TECH BULLETIN

9402:

MATV/MASTER ANTENNA SYSTEMS

-ABOUT TECH BULLETIN-

Tech Bulletin is produced and distributed by technology author and researcher Robert B. Cooper five (5) times per year. **Tech Bulletin** selects a single 'topic' for discussion and devotes one or more issues to the selected topic such that readers/users may utilise the material for reference and business planning.

In 1993, Tech Bulletin's five issues covered: (**9301**) Co-Channel television interference solutions, (**9302**) VHF fringe area reception and antenna practices, (**9303**) UHF fringe area reception and antenna practices, (**9304**) Eliminating man-made noise sources from VHF and UHF reception, (**9305**) Cable TV Basics: Part one of two. Copies of single issues remain available ($15 each) or the complete five issue set is available for (NZ) $60.

1994 Tech Bulletins (will) deal with (9401T) Cable TV Basics: Part Two, (9402T) MATV/Master Antenna system planning (this issue), (9403T) VHF/UHF TV Receiving Antenna Design Tricks (available May 18), (9404T) C and Ku Band home satellite systems (available July 05), and, (9405T) Commercial satellite installations in motels, clubs (available October 10).

1994 issues are $15 each (New Zealand) or $60 for full year, from:

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TECH BULLETIN 9402(T)- MATV/MASTER ANTENNA WIRING TECHNIQUES

The basis for master antenna television (MATV) could have been rooted in domestic water distribution systems. A pressure (measured as a signal voltage) enters a pipe (a transmission cable) and flows through the pipe system (further cabling) to faucets (master antenna wall outlets).

The water pressure available at each faucet depends upon the original pressure divided by the number of faucets operating simultaneously but limited by the capacity (diameter) of the piping system.

In a master antenna system one or more VHF and/or UHF channels of television, perhaps including FM band broadcast signals, are received by antennas designed to produce the best possible reception quality. If two or more antennas are required for the different frequencies or different antenna 'headings' (direction to the transmitters), the (plural) antennas are combined to a single 'line' such that they do not interact.

The signal levels present at the antenna installation (called 'headend' in the trade) must be sufficient to allow division to each of the planned receiver locations. Here there are two factors to be considered:

#1) The signal voltage required at each of the receiver locations, and,

#2) transmission losses between the antenna (headend) and each receiver location.

It is the 'transmission losses' in cable which make coaxial cable distribution systems slightly more challenging than plumbing a house for water.

CABLE LOSS BASICS

Although it is possible to distribute VHF/UHF signals within a building, or group of buildings utilising parallel conductor cables (such as 300 ohm 'twin lead') there are several excellent reasons why this is never done by a professional installer. Here are some of those reasons:

#1) Parallel conductor lines have very poor rejection of interference sources. And although it is possible to locate 'shielded twin lead', the degree of shielding (i.e., the measured ability of such cables to prevent signals from outside the cable coupling into the cable's parallel conductors) is at best poor.

Because it is virtually impossible to avoid running MATV cabling along side of, parallel to, or across electrical and other cabling during installation, the parallel conductor cable acts as both a transmission line for the intended signals and an antenna to pick up undesired radiation sources. Once such undesired signal sources penetrate into the parallel conductor cable the interference becomes intermingled with the desired signal. The result is degradation of the desired signals.

#2) The flat or oval shaped parallel conductor cable increases the difficulties with installation. Passing the cable through walls, across metal window or bulkhead liners, along metal roofs allows the metallic surfaces to distort the magnetic pattern established in the twin, parallel conductor wires.

The net result is degraded performance for the parallel conductor wire when it is in close proximity to metallic surfaces. Running a length of twin conductor line parallel to a metallic roof for a short distance of 1 metre at a distance of 10 mm from the roof can reasonably be expected to reduce the signal within the line by 50% (3 dB) at 600 MHz (TV channel 37).

#3) All formats of parallel conductor lines have increased attenuation when wet. A line rated at 3 dB of loss per 33 metres at 600 MHz, when dry, can escalate to 10, 20, even 23 dB (!) for the same length of line when wet.

While modern parallel conductor lines using 'air' as a spacer between the parallel wires, or foam dielectric as a spacer are less prone to 'wet weather losses', they are not immune to such losses.

#4) Parallel conductor lines must for their own safety and performance be 'suspended' away from all surfaces, not just metallic surfaces. This means the lines must be supported at regular intervals with some type of 'stand-off insulators.'

Stand-off insulators increase the complexity of an installation, raise the cost, and are themselves subject to mechanical failure when exposed to weather. Installing parallel conductor ('twin lead') without stand-off insulators is extremely poor practice; installing twin lead with stand-off insulators is a pain in the neck for the installer.

The answer to these (and additional) problems is coaxial cable. Parallel conductor cables are in a family of 'balanced conductor cables' where either side (half) of the circuit carries approximately 50% of the total circuit signal voltage. In a parallel conductor 'balanced' system, you may reverse the two parallel wires at terminals connected to the system and anticipate the system performance will be the same regardless of which side of the parallel wires is connected to which end-of-line terminal.

Coaxial cable is unbalanced because the majority of the energy transferred through coaxial cable is carried by the centre conductor. There are two conductive paths in coaxial cable; a shield of conductive wire or metallised 'tape' is the second electrical path in the system. If you reverse the centre conductor and the shield at the terminals of a coaxial cable network termination (end of line) point, you can reasonably expect an instant degradation or total loss in the service delivered by the cable.

Coaxial cable can be visualised as a 'single electrical conductor' with a 'ground return;' the shield. However, the shield does more than provide a ground return; it also protects the centre conductor from the ingress of interference from outside sources. 'Shield' then is a descriptive term as well as a name for a portion of the cable proper.

In any serious installation for MATV we utilise coaxial cable as the transmission medium because it is nearly immune to interference that might otherwise be picked up by the cable itself, it can be laid directly on or run through metallic surfaces without performance degradation, it has identical losses whether dry or wet, and it requires no special stand-off insulators or other equipment to install.

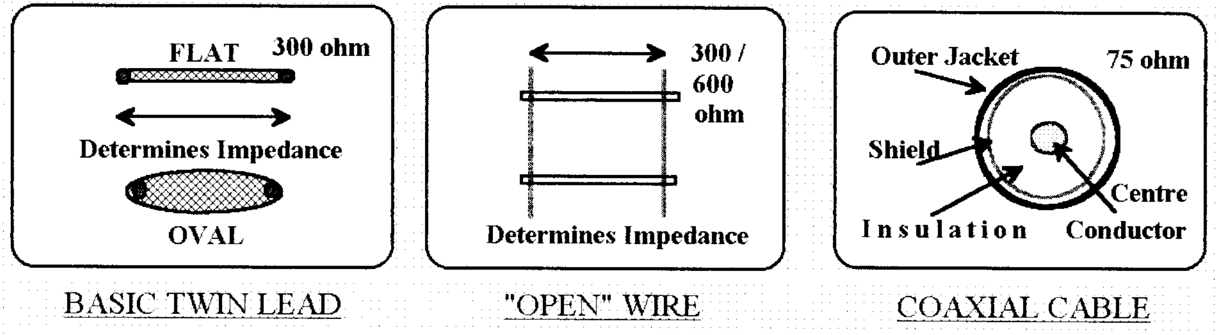
LOSSES IN CABLE

It is true that for any given frequency (whether TV channel 1/45 MHz or TV channel 62/800 MHz) you can buy or build a parallel conductor (i.e., twin lead) transmission line that will have less loss per unit of length than commonly available coaxial cable. If cable loss between the antenna and the TV set is the only consideration, coaxial cable might be a poor choice (see Tech Bulletin **9302**; p.22).

In all transmission cables (whether parallel conductor or coaxial) there are losses. Most suppliers provide technical data concerning their cables and rate cable losses as a function of frequency. In all RF transmission cables the losses increase as the frequency increases. These losses are a function of conductor (wire) diameter and the choice of insulating material between the two conductors. 'Wet' twin lead losses increase over dry twin lead because the appearance of water on the surface of the twin lead changes the dielectric (insulating) qualities of the plastic insulation material. In parallel conductor/twin lead wires the magnetic energy field formed by the signal voltages being transported within the wires is several times larger than the wire's physical dimensions. Thus the outer side of the twin lead, when wet, becomes a 'body of moisture' appearing inside of that magnetic field and this water film does nasty things to the field itself; increasing the cable losses in the process.

Coaxial cable contains its magnetic field within the shield of the cable; the shield not only appears as a physical barrier to the ingress of interference originating outside of the cable,

ANATOMY OF TRANSMISSION LINES



BASIC TWIN LEAD "OPEN" WIRE COAXIAL CABLE

it also acts as a barrier to prevent the magnetic energy field of the transported signals from leaking to the outside of the cable.

You can prove this to yourself by sending a reasonably powerful TV signal first through a length of TV twin lead, and then through a length of coaxial cable. Use a TV set with a 2 metre length of twin lead connected to the antenna terminals as a 'sniffer' and place the sniffer length of twin lead up close to the signal carrying twin lead, and then up close to the coaxial cable. When your sniffer length of twin lead is close to (within the magnetic wave field of) the twin lead transmission line, you will be able to 'tap into' the twin lead without actually making a physical connection to the line. The signal literally radiates from the twin lead transmission line into your sniffer antenna and then is carried to the TV set. With coaxial cable you will have no radiation and no signal pickup.

Transmission line losses are quantified by the decibel unit. By using a TV signal level / field strength meter we can measure the amount of signal present on any given TV channel or FM radio frequency. The field strength meter (FSM) is a frequency selective voltmeter. It consists of a tuning device that selects one specific TV carrier frequency (either the visual carrier or the audio carrier), a series of calibrated amplifier stages, a detector network and a display system that tells you within the accuracy ability of the FSM just how much signal you have at a given frequency.

The decibel unit of measurement is a standard used in many radio and TV fields. It can be a very confusing unit of measurement.

The 'bel' is the root word and comes from an abbreviation of Bell as in (Dr.) Alexander Graham Bell. The 'decibel' means one tenth of a bel (from deci as found in the metric system). That seems clear enough. Unfortunately for those who are accustomed to measuring volts or mils of current where '1 volt' or '30 mils' is a hard, definable number of known quantity, a signal level of '10 decibels' (10 dB) means absolutely nothing unless you know more.

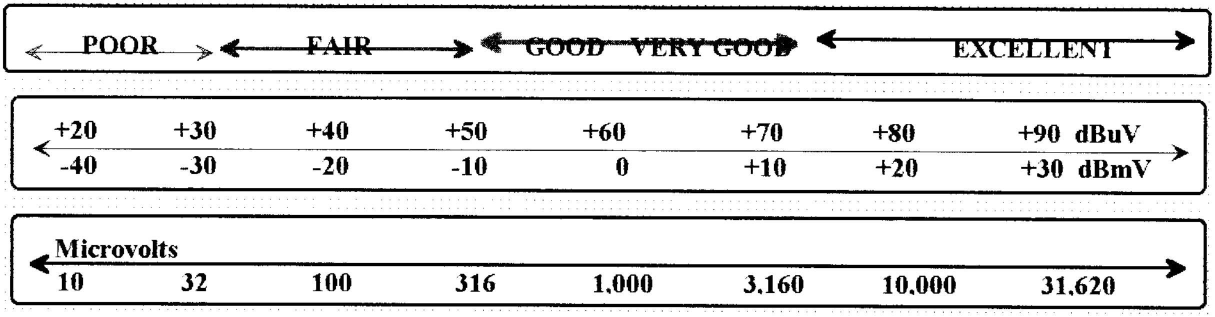
To the inventor of the telephone, the 'comparison of loudness' was a very important factor and the 'bel' answered this need. But measuring loudness was elusive. A voltmeter will tell you when there is no voltage present but nothing existed at the time to tell you when there was no sound present. Or more importantly, while a voltmeter will tell you when the voltage changes from 1 volt to 2 volts, how could Mr. Bell measure sound that 'doubled in loudness?'

In any use of the 'bel' we are measuring comparisons between either two separate levels or between our measured level and some industry reference.

In the audio recording field all sound levels are referenced to one milliwatt carried by a 600 ohm line. Audio 'VU' meters are calibrated in dB 'units' where 0 dBm is the 'reference level.'

In TV receiving systems signal levels also use a 0 (dB) reference point. In the case of audio

WHAT DO SIGNAL LEVEL NUMBERS MEAN?



engineering, 0 dBm is actually 1 milliwatt on a 600 ohm (impedance) line. In TV receiving systems 0 dBmV is 1,000 microvolts (1 millivolt, .001 volt) on a 75 ohm line. Thus 0 dB(mv) in TV is not a total lack of signal since 1,000 microvolts is actually quite a fair amount of signal.

1,000 microvolts was selected as the '0 dB point' for TV systems in 1950 by an American TV equipment manufacturer; Jerrold Electronics (now General Instruments). The first published data referred to 0 dBj where quite selfishly Jerrold added the first letter of their firm name to the measurement unit. In time the industry became accepting of the practice but not of the 'j'. Since 0 dB was 1,000 microvolts or 1 millivolt, '0 dBmV came to mean 'a signal 0 dB stronger than 1 millivolt.'

The 1 millivolt signal level, established as the TV 'reference point,' has a sound engineering basis. For the typical television receiver, it takes something approximating 1 millivolt of signal (on a TV channel) to produce an interference free, 'fine grain' TV picture (see Tech Bulletin **9301**; p.6). Thus 0 dB is a statement about 'standard picture quality.' A signal weaker than 0 dB is likely to be degraded from a 'quality picture' used as a reference, a signal stronger than 0 dBmV is going to have 'margin' above 'quality.'

Since 0 dBmV is not a total lack of signal (as 0 volts is a total lack of voltage), it follows that we can encounter minus dBmV numbers and plus dBmV numbers in the real world. Most signal level / field strength meters have a dial face or meter scale on which is printed dB scales. Most such meters have a series of signal attenuators (slide switches or push buttons) which allow you to change the range over which the meter reads for full scale. The actual level read on the meter face represents a signal that falls within a range of levels; such as a 20 dB 'window.' We'll return to this point.

dB 'WHAT' V?

In North America where FSM/SLMs are regular tools of antenna system and cable installers, analogue meters are typically calibrated so that the meter face represents a 20 (up to 22) dB 'window' of signal levels. The standard reference of 0 dBmV is usually indicated with a coloured mark (red) and the meter attenuators are somehow calibrated to help the user find 0 dBmV quickly. Most modern meters have replaced analogue (dial face instrument) with digital reading displays and the user reads out the exact signal level present by simply noting the illuminated digits in the display (such as +32.3 (dBmV)).

The European tradition recognises the origins of decibels but takes a different approach. Although Europeans still recognise that a decibel is a unit of comparison and not an absolute value, rather than accepting 0 dBmV as a point of reference, European meters begin with zero signal (i.e., like zero volts on a voltage meter) as a point of reference. To help keep this

European standard distinct from the North American / cable TV industry standard where 0 dBmV equals 1,000 microvolts (1 millivolt), European meters calibrated with 0 volts as 0 dB call their scale the dBuV (where the u is the Greek symbol u) scale. We show the comparison here and note that it is unfortunate that after nearly 50 years of everyday use there is not a single standard for TV signal level measurements world wide.

As a quick point of reference, an American 0 dBmV is the same as an European +60 dBuV while a European 0 dBuV is the same as -60 dBmV in North America. Most installer signal level meters available in the South Pacific (i.e., New Zealand and Australia) originate either in Europe or have been built following the European example.

However, a decibel is one tenth of a bel in both systems and a 3 dB signal increase (or decrease) means the same thing in Chicago as it does in Auckland or London.

dBs OF GAIN / LOSS

If signal levels were measured only in absolute values, planning a MATV (not to speak of a CATV) system would be an exercise in very tedious math. An example:

a) 0 dBmV / + 60 dBuV is 1,000 microvolts.

b) -3 dBmV / +57 dBuV is 707.9 microvolts

If you were measuring comparative signal gains of an antenna would you rather be recording in your notebook '0 dB' (or +60) and '-3 dB' (or +57), or, 1,000 and 707.9?

Another example:

a) At the end of a 500 metre length of coaxial cable you measure 141.3 microvolts of signal on channel 11 and 501.2 microvolts of signal on channel 2.

Question: How much stronger is channel 2 than channel 11?

The answer is 359.9 microvolts,

But, 141.3 is the same as -17/+43 (dB) while 501.2 is the same as -6/+54 (dB). Now the

10 Microvolts	-40 dBmV	+20 dBuV
14	-37	23
20	-34	26
28	-31	29
40	-28	32
56	-25	35
79	-22	38
112	-19	41
159	-16	44
224	-13	47
316	-10	50
447	-7	53
631	-4	56
891	-1	59
1,000/1 mV	0	60
1,410	3	63
2,000	6	66
2,820	9	69
3,980	12	72
5,620	15	75
7,940	18	78
11,220	21	81
15,850	24	84
22,390	27	87
31,620	30	90
44,670	33	93
63,100	36	96
89,130	39	99
125,900	42	102
177,900	45	105
251,200	48	108
354,800	51	111
501,200	54	114
707,900	57	117
1 volt	60	120

quick-to-see answer is "There is 9 dB of difference between channel 2 and channel 11."

Amplifiers are rated by the dB of gain they provide; passive devices such as splitters are rated by the '(dB of) loss' through the device. Can you figure out a suitable method of telling a user that the amplifier will provide a gain of 20 dB or the passive will have an input to output 'loss' of 4 dB using only microvolts / millivolts?

Decibels (dBs) can be quickly added and subtracted; microvolts cannot. If you start out with 0 dBmV/ +60 dBuV of antenna signal, go through a 20 dB gain (dBg) amplifier, you have +20 dBmV/ +80 dBuV of signal level available. If you then send the signal through a length of cable which has 11 dB of 'loss' before reaching a signal splitter with 4 dB of additional loss, you can determine the signal level after the signal splitter by merely taking +20 dBmV / 80 dBuV and subtracting 11 dB for cable loss (now +9/+69) and then subtracting 4; +5 dBmV / +65 dBuV. Try that using only microvolts/millivolts! It simply becomes not computable.

Decibels, then, are a shorthand system that makes planning (on paper), installing and maintaining RF distribution systems manageable.

ELEMENTS OF A 'GOOD PICTURE'

The objective in any MATV distribution system is to deliver to the individual TV/FM receiver outlets connected to the system a good picture. Virtually every system designer agrees that 1,000 microvolts / 1 millivolt / 0 dBmV / +60 dBuV is a 'good picture.' This statement makes a few assumptions.

That any degrading 'signals' are so much weaker than our 'good picture' level that the viewer sees no objectionable degradation (see Tech Bulletin **9301**; p.6). 0 dBmV / +60 dBuV will produce a 'good picture' only when there is no interference present. A source of co-channel interference, for example, which accounts for 50% of the 1,000 microvolts present at the TV set will have devastating affects on the picture (see Tech Bulletin **9301**, p.4). So too would a source of electrical interference generating 200 microvolts of signal which is fighting for the viewer's attention even with 1,000 microvolts of TV signal present (see Tech Bulletin **9304**; p.11). Unfortunately for the installer, the FSM / SLM probably cannot tell the difference between a pure 1,000 microvolts of signal and a signal level that reads 1,000 microvolts that includes some form of degrading interference. We'll return to this subject.

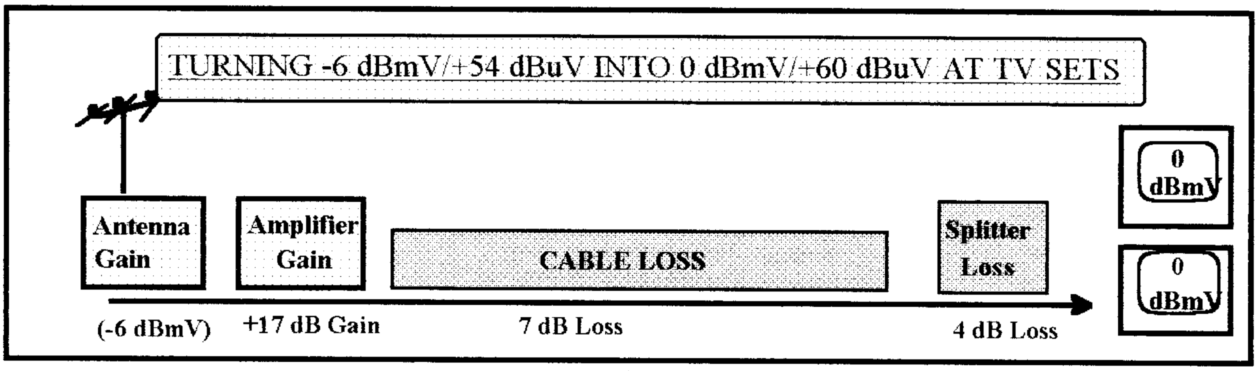
ELEMENTS OF GAIN AND LOSS

Any cable distribution system has building blocks of gain and loss. An antenna is considered a 'gain block' because the installer has the ability to select a receiving antenna configuration that can build up (make stronger) the received signal level beyond a level which might be considered 'normal' for a given location (see Tech Bulletin **9302**; p.8).

A masthead preamplifier is a 'gain block' as is a distribution amplifier. Anything that 'adds' dBs to the system is a gain block.

Coaxial cable is a loss block because even a short run of cable will attenuate signals transported. Signal splitters, signal tap-off devices are also 'loss blocks.'

In its most basic form, you are attempting to connect each TV set outlet in the system to a point within the system where the TV set is guaranteed a 'good picture;' or, 1,000 microvolts. If the receive antenna is only capable of creating a signal that is 500 microvolts (6 dB less signal than you need for a 'good picture'), it follows that the absolute minimum gain you require in a gain block is 6 dB (to reach 1,000 microvolts). If the coaxial cable from the antenna to the TV set will have 7 dB of loss, now the absolute minimum gain you require in our example is 6 dB to reach 1,000 microvolts at the antenna system output



plus 7 dB to overcome connecting cable losses; or 13 dB total gain. And, if the TV outlet location is actually two outlets for two TV sets, then we must 'add' the loss of the two-way signal splitter; another 4dB. Now we need a total of 17 dB of amplification (or gain block) to reach both of our TV sets with no less than 1,000 microvolts; a 'good picture.'

Planning any MATV system is an exercise in simple sums when using the dBmV or dBuV scales. The 'answer' to the problem is always known in advance; 0 dBmV or +60 dBuV is to be made available at each outlet in the system. If you know or can determine distances (how many metres or feet of cable will be required between the antenna and successive outlets connected to the system) these distances can be converted to dBs of cable loss. As you plan the system adding line-signal-splitters and receiver outlet signal tap-off devices, manufacturer data sheets will tell you how much 'loss' to assign to each such unit required.

When the system is paper complete, drawn out as a wired network that connects each signal outlet location back to the antenna (headend), there before you will be both a 'schematic' of the system and a 'loss diagram' for the system. To compensate for the cable and passive device (splitter/tap-off) losses, as a last planning step you 'plug in' to the diagram a 'gain block' or amplifier. In its most basic terms, the amount of gain you require will be equal to or slightly more than the combined cable loss and passive losses at the most distant signal outlet in the system. If the 'sum' of all cable and passive losses to the last outlet is 27 dB then you need something approximating 27 dB of 'gain block' in the system to replicate the same signal level / quality found at the headend at each of the receiver locations.

THE HEADEND - Getting The Inputs Right

The pictures delivered to the TV outlets can be only as good as the original quality at the antenna. With clean antenna signals of 0 dBmV / +60 dBuV or more no additional processing is likely to be required although something called 'signal balancing' may be valuable. If the desired input signals can be received at relatively uniform signal levels from a single (broadband) antenna with adequate (0 dBmV / + 60 dBuV or better) levels, the planner can move forward to the system 'sums.'

More often, however, at the very least the antenna level signals will vary in level from channel to channel. Some variation is acceptable just as we come to expect variation in signal levels with one antenna / one TV set home systems. Variation in signal level, between channels, becomes a problem for the MATV system planner only when the 'gain block' (system amplifier) finds it difficult to properly amplify signals of widely varied input levels.

Ideally, each channel to be cable distributed will arrive at the antenna within a 'dB window' of +/- 3 dB. Real numbers: Assume channels 2, 4 and 7 with antenna-output measured levels of +6 dBmV / +66 dBuV worst case and +9 dBmV / +69 dBuV best case. The variation of levels is 3 dB; well within the suggested +/- 3 dB 'window (which is actually a 6 dB spread).

However, suppose you find channel 2 to be +6 dBmV / +66 dBuV while channel 7 is +12 dBmV / + 72 dBuV? What makes this undesirable?

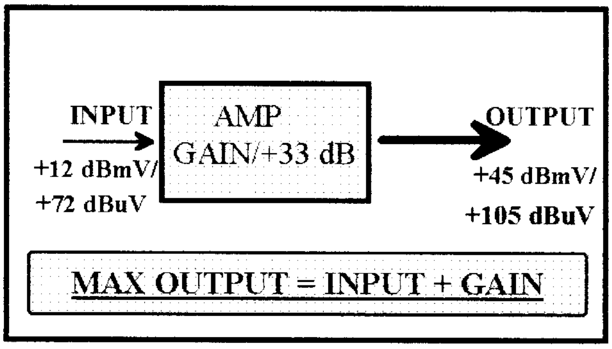
If one or a few TV sets are connected to this antenna-output signal, the TV set's internal AGC (automatic gain control) will handle any channel to channel variations of this magnitude. And as long as the weakest channel arrives at each TV set connected to the antenna with 0 dBmV / +60 dBuV or better signal level, you can be confident that all channels will have a 'good picture.'

Now add an amplifier to the system to compensate for cable and passive losses. Amplifiers are rated for their gain (in dBs of gain), their noise figure (also in dBs; see Tech Bulletin 9302;p.9), and, their signal handling capability. It is the signal handling capability that concerns us here.

All amplifier devices have a maximum rated output, specified as:

Maximum output level for 1/2 dB sync compression: +XX dBmV / XXX dBuV.

Maximum rated output for any installation is straight forward to compute. Take the known dB gain rating of the amplifier (say 33 dB) and add it to the strongest antenna level signal at your chosen site (say +12 dBmV / +72 dBuV). 33 + 12 is +45 dBmV (or 33 + 72 is +105 dBuV). Now read the manufacturer's data sheet: is the amplifier capable of +45 dBmV / +105 dBuV maximum output?

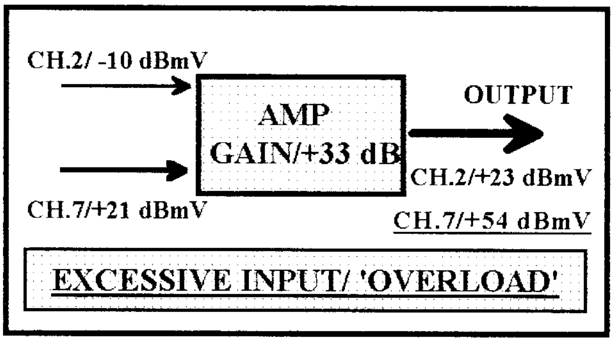


All amplifiers have a maximum number of channels that can pass through the gain block without undesirable effects. Older style units (using bipolar transistors in a 'single-ended' type of circuit) typically limited the user to fewer than 20 channels of TV. Newer style units with 'push-pull,' 'hybrid,' 'power-add' or other low distortion circuitry have 'maximum channel' numbers of 35 or greater. In our own environment with typically 3 to 9 TV channels in a location, obviously maximum channel criteria should not be a consideration.

Now consider a situation where one channel is very strong from the antenna, and one is very weak in level. For numbers let's assign +21 dBmV / +81 dBuV to channel 7 and -10 dBmV / + 50 dBuV to channel 2. If our amplifier has 33 dBg (dB of gain) the channel 7 output levels from the amplifier become 21 + 33 = +54 dBmV (81 + 33 = +114 dBuV) and channel 2 becomes (-) 10 + 33 = +23 dBmV (50 + 33 = 83 dBuV) . Note that the original difference in signal levels (31 dB) found before the amplifier is also found after the amplifier; the numbers have increased by the 33 dB of gain but the relationship is unchanged.

Our amplifier data sheet says the maximum output level is +48 dBmV / +108 dBuV. Obviously one of our two channels exceeds this level by 6 dB. So what happens?

In this example two undesirable problems arise. First, the stronger of the two signals (channel 7) has its video sync components 'clipped' or chopped off by the amplifier. The degraded sync signals within our channel 7 signal will cause the TV set to fight harder to



maintain sync lock; most likely the picture will 'roll' vertically. This degradation on channel 7 is intolerable.

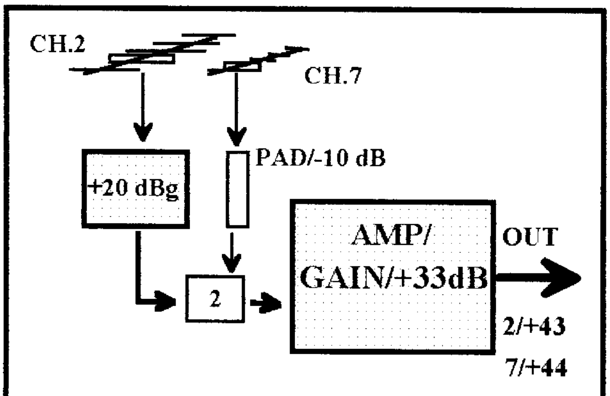
At the same time because of the overloaded condition of the amplifier output stages, the actual sync and video modulation from channel 7 will transfer onto the weaker channel 2 carrier. This will create a channel 2 picture that contains a floating second image coming from channel 7. This effect (called cross modulation) is equally intolerable.

So although the TV sets connected to the MATV system might be capable of handling inputs with signal variations as great as our 31 dB example, the system amplifier in this example cannot function properly. Obviously something must be done to 'balance' the two inputs (bring them closer together in level), or at the very least find an amplifier than can handle a +21 dBmV / +81 dBuV input on channel 7 without going into 'distortion' (in this example, the amplifier would have to be capable of outputs greater than 54 dBmV / +114 dBuV).

The correct choice is to balance the input signals. This can be accomplished in a variety of ways.

In our example we have one band I signal (channel 2) and one band III signal (channel 7). If the wide variation in input levels is from a single, common, receiving antenna the easiest answer is to install two separate antennas; one for channel 2, one for channel 7. In doing this we can a new opportunity to increase the channel 2 signal, and actually attenuate the channel 7 signal with the objective of bringing the two levels closer to the same dB reading at the input to the common amplifier.

In the case of channel 2 the simplest fix is to add a masthead preamplifier to the channel 2 (only) antenna. If 20 dBg of masthead is added to the original -10 dBmV / +50 dBuV channel 2 signal, our new channel 2 level is +10 dBmV / +70 dBuV.



RE-BALANCING INPUTS

In the case of channel 7, we can reduce the signal level present by placing a 10 dB in-line attenuator between the channel 7 (only) antenna and the 'mix point' where channels 2 and 7 are combined. With a 10 dB attenuator the +21 dBmV / +81 dBuV signal is +11 dBmV / +71 dBuV. The 1 dB level difference between channels 2 and 7, after these adjustments, is very tolerable. And if we now send the combined channel 2 and 7 signals into a 33 dBg amplifier, the outputs are in the +43/44 dBmV / +103/104 dBuV region. The same amplifier with +48 dBmV/+108 dBuV maximum rated output now runs quite safely.

Balancing inputs to a system (before the first all-channel amplification) is an important element in any MATV system but is often bypassed as an unnecessary step. It is not unnecessary and if you seek to install MATV systems as a part of your regular business activity, this one relatively simple step can do more to establish your reputation as a quality installer than perhaps anything else you might do.

BALANCING OPTIONS

Signals that are too strong must be attenuated (this may seem like a backward step since you will later amplify the signals in a broadband amplifier) while signals that are too weak must be pre amplified. Sometimes you can make this balancing adjustment with antenna selection and no masthead units.

Individual antennas for each channel would be the ultimate (CATV/cable TV) solution. Unfortunately, not only is this an expensive route but your installation will probably also require individual headend electronics for each channel as well. More typically, a separate antenna for band I and another for band III will solve many balancing problems.

Two or more antennas can be inexpensively 'combined' to a single 'trunk line' (the cable that leaves the headend area going towards the actual receiver locations) using passive splitters. A splitter, wired up in reverse, becomes a combiner. A two-outlet splitter can be fed band I through one port, band III through a second port. The intended input becomes the output and each band now appears at the input-becomes-output port with a reduction in signal level equivalent to the normal splitter loss (such as 4 dB for a two-way unit). We diagram that here.

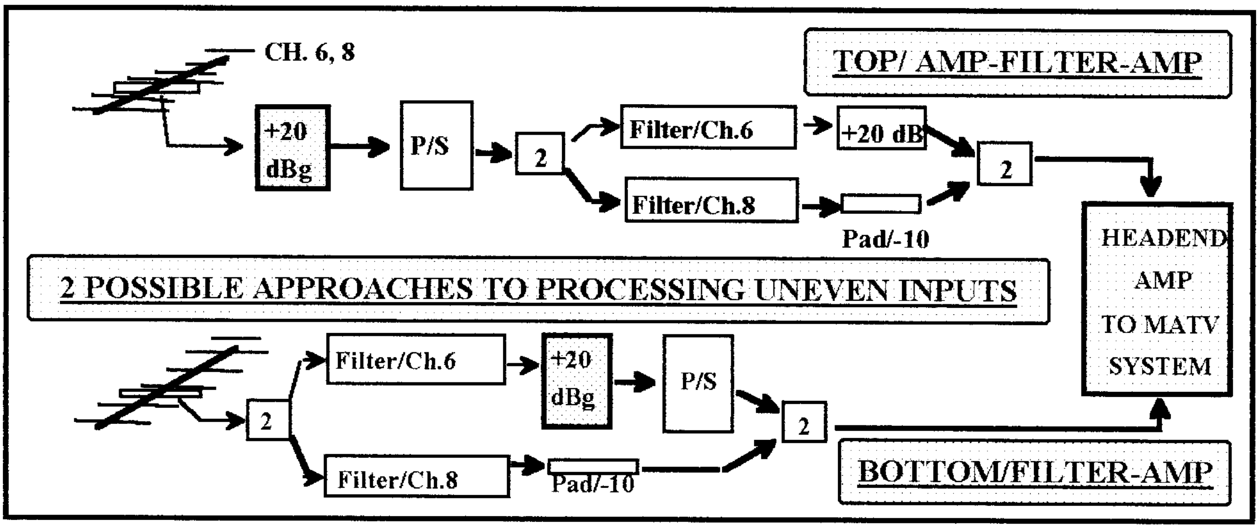
As earlier noted, separate plans can now be employed for band I and III signals using mastheads or attenuators as required between the individual band antennas and the input to the 'combiner.' The only special consideration is to select a splitter/combiner that is capable of passing AC power if you will have a masthead unit at one or both of the separate band antennas.

If your situation has a wide variation in signal levels between two or more transmitters within a single band (such as channels 4 and 7 in band III), the solution becomes more complex although the principal is the same. First, can you do anything with the antenna system (Tech Bulletin **9302**; p.25) to balance the two band III signals? Perhaps by using separate antennas for the two channels, using a stacked array on one channel and a single yagi on the stronger channel, you will be able to do balancing. This is a suitable solution if there are significant differences in signal arrival directions (channel 4 due north, channel 7 due east for example) or if one of the signals is vertical and the other is horizontal. The major challenge is to keep channel 4 from being received at level on the channel 7 antenna and vice versa since ghosting (multiple images offset in time from one another) can easily occur when there are two or more electrical paths for the channels to follow.

If this (cross over) problem occurs with separate band I and III antennas, the least expensive solution is to substitute a 'band separator' for the two-way splitter used as a combiner. The band separator is nothing more than a two-way splitter/combiner that has a degree of frequency selection built in. One leg is marked for band I, the other for band III. Band I signals passing through the band III leg are attenuated by typically 30 dB and vice versa. The result is that any ghost-causing signals picked up by the 'wrong' antenna are attenuated by the frequency selection of the separator.

When two or more signals requiring separate headend processing are in the same band and you cannot 'isolate' the two signals using antennas (through phasing - Tech Bulletin **9301**, through stacking - Tech Bulletin **9302**, or through polarisation differences - Tech Bulletin **9304**), single channel processing techniques are mandatory. This means frequency selective (bandpass) filtering has to be placed at the headend to individually separate the two (or more) same-band signals. Once the signals have been separated, you can proceed to amplify or attenuate them as required before recombining the signals into the master 'trunk' line.

Separating individual channels for pre-trunk distribution involves filtering. There is no reliable alternative to separating channels one at a time into their 7 (8) MHz bandwidths. Even when two or more channels are received by the same antenna they can be filter isolated such that the installer can then further process the individual channels before recombining them to the trunk.



Not surprisingly, such a filter is known as a bandpass filter (or passband filter, essentially interchangeable terminology). Such a filter consists of a series of tuned circuits not unlike the i.f. filters found in a television receiver. At either end of the series connected filter sections are tuneable traps which precisely attenuate the two adjacent channel carriers (audio carrier on low channel side, visual carrier on high channel side). Typical specifications include:

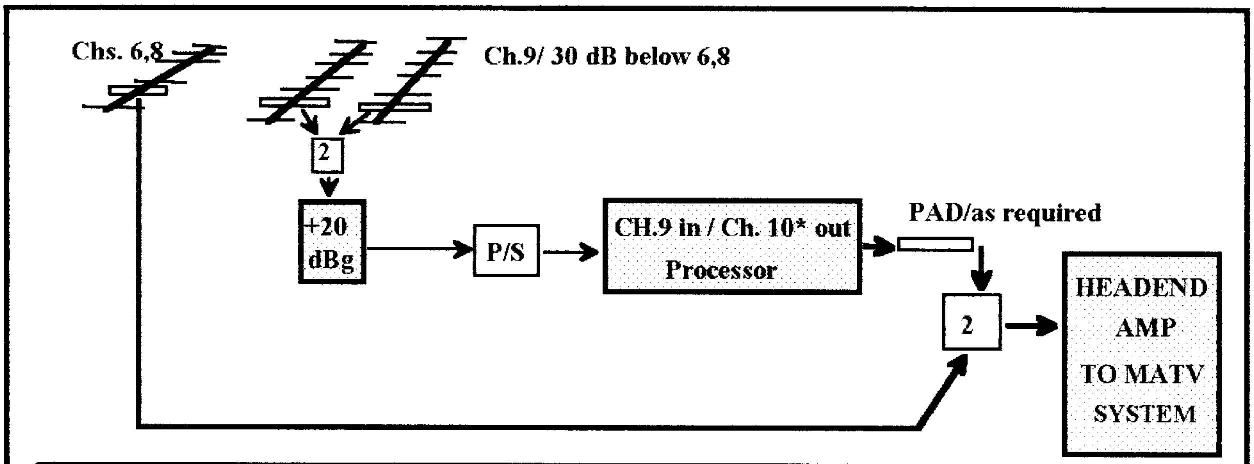
a) Bandpass - 5.0 MHz (Pal B; 6.0 MHz PAL-D)
b) Attenuation of carriers:
  Lower adjacent channel aural -60 dB
  Lower adjacent channel visual -40 dB
  Upper adjacent channel visual -60 dB
  Upper adjacent channel aural - 40 dB
c) In channel flatness +/- 1.5 dB
d) Insertion loss 4.0 dB

These are 75 ohm devices, typically designed for rack mounting, 'F' series connectors.

Depending upon your actual situation, the filters could follow a broadband (or band I or band III only) masthead amplifier / signal splitter, or, if masthead types of gain (i.e., 20-30 dB) are required on specific channels, the antenna(s) would feed through a signal splitter into the bandpass filters and then into masthead type preamplifiers. Most bandpass filters will not pass AC power so power supplies for mastheads must be located before the bandpass filtering.

Note the thru or insertion loss parameter of bandpass filters. While 4 dB is manageable, it must be considered when planning where the amplification will go. An off-air signal that is -20 dBmV / +40 dBuV wants to be amplified before filtering since the additional loss sustained in any signal splitter and bandpass filter ahead of the amplification would carry the channel's signal to noise ratio down into the never-never land of high noise (see Tech Bulletin 9302; p.8). In a really bad situation, with one or more strong in-band signals and a weak same-band signal as well (all to be balanced at the headend) you should first consider two separate sets of antennas; one for the stronger signals and another for the weaker signal. In this way you avoid the single antenna - splitter loss of the splitter (4 dB is 4 dB) and may be able to arrange the antenna for the weaker channel (through stacking or antenna selection) such that you gain a few precious dB of signal on the weaker channel. Any masthead units selected which will process both the weak signal and the stronger signal(s) must be capable of handling the output level of the stronger signal(s) after amplification.

There is another approach as well. It is called a 'channel processor'. The stronger signals present no special problems; in the worst case you will need to attenuate the signals for balancing and perhaps take steps as discussed to



MUCH WEAKER same-band signal is run through 'channel processor' to isolate it from stronger same-band signals; if 'adjacent', processor gives it new output channel.

eliminate any possible ghosting paths for the stronger signals through the weaker channel(s) equipment.

A channel processor is a RF (input channel) to i.f. (for signal filtering, processing, gain and AGC) to RF (output channel) device. It functions in exactly the same way as a TVNZ/TV3 television translator. The input signal is received on its off-air channel, frequency converted to an i.f. where the signal is separated from all other same-band signals, amplified to a higher level, and fading is controlled with an automatic gain control system. The processed channel is then frequency translated from the i.f. back to either its original input channel or to a new channel chosen by the system installer.

Consider a situation where TVs 1 and 2 are available at good level but TV3 is perhaps 30 dB weaker. If you erect one antenna for TVs 1 and 2, another for TV3 and then attempt to balance the signals by placing a masthead on the TV3 signal (and perhaps attenuators on the TVs 1 and 2 signals) before combining, you may end up with TVs 1 and 2 'leaking' through the TV3 system; ghosts. Bandpass filters for all three channels would clean it up; perhaps a bandpass filter only on the TV3 system would also clean it up.

Another solution is to take the TV3 signal into a channel processor and then bring it back onto the system on a new (you select) TV channel. If TV1 is on channel 6, TV2 is on channel 8 and TV3 is on channel 9 off-air, placing TV3 back into the system (after processing) on channel 9 is not intelligent since you will now be asking the MATV system connected TV sets to properly separate 8 from 9. In a cable system (see Tech Bulletins 9305, **9401T**) this is an acceptable practice since all channels are carefully controlled in level and the individual TV sets have no difficulty separating adjacent channels as long as their respective levels are uniform. In a lower-dollar MATV system, it makes more sense to move our example TV3 signal off of channel 9 (such as to 10 or even 2) by simply allowing the channel processor to operate on a different output channel.

Channel processors in PAL-B format are available in two design modes:

a) You specify the input and output channel(s) desired when ordering;

b) you pay more money for the channel processor but gain the ability to field-set the input and output channels yourself (typically to any input/output in the range of 47 to 862 MHz).

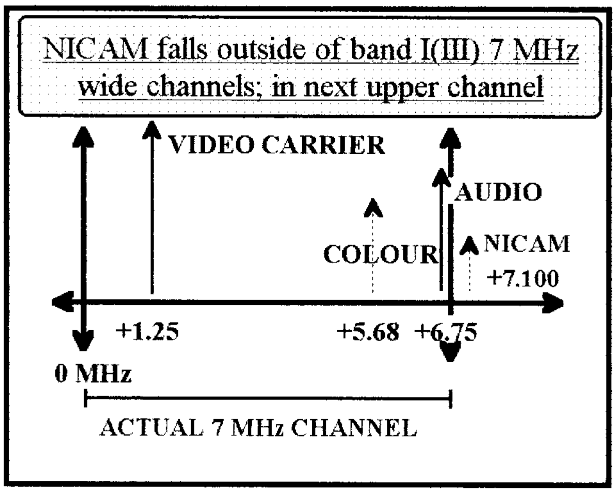
Another advantage to the channel processor approach is that the unit has circuit gain built-in;

with an input as low as -15 dBmV / +45 dBuV from an antenna or masthead preamplifier you can create an output (on the channel selected) of +60 dBmV / +120 dBuV. (Yes, that is approaching the kind of level one might need for re-radiating directly through the air for a local service translator but nobody reading this would ever consider such an option, of course.)

The disadvantages to channel processors are cost (around NZ$1500 each in the fixed input/fixed output channel format, $2,400 in the fully agile format), and, NICAM. Most of the PAL format units do not allow for the extra bandwidth required for NICAM (falling as it does 5.850 MHz above the visual carrier and therefore actually inside of the next upper adjacent channel). On the other hand, very few MATV connected motel sets feature NICAM so the loss of NICAM stereo may not be a serious consideration.

Note: Bandpass filters designed for standard PAL-B channels will exhibit the same no-NICAM problem since the upper channel passband limit is just above the regular audio channel (i.e., + 5.5 MHz) and will cut off before the special NICAM sub-carrier which resides + 5.850 MHz above the visual carrier. There is an expensive solution to this and information can be provided upon request.

Typical channel processor specifications include:


NICAM falls outside of band I(III) 7 MHz wide channels; in next upper channel
VIDEO CARRIER
AUDIO
COLOUR
NICAM
+7.100
+1.25
+5.68
+6.75
0 MHz
ACTUAL 7 MHz CHANNEL

a) Frequency range: Any input channel in the frequency range 47-862 MHz. Any output channel in the 47-550 MHz range.

Note: New Zealand TV channel one (44-51 MHz) is unique in the world and except on very special order, channel processors are not available for this channel. As a practical matter, modern varactor tuned TV sets ignore 'channelling' per se and if an MATV system outputted on channel 1+ (48.25 to 54.00) and the system did not have a channel 2 signal in it (i.e., 54-61 MHz) there would be no problem with 'tracking' TV set tuning to a 48.25 visual carrier frequency established by the processor.

b) Minimum recommended input: -15 dBmV / +45 dBuV.

c) Maximum output: +60-65 dBmV / +120 -125 dBuV.

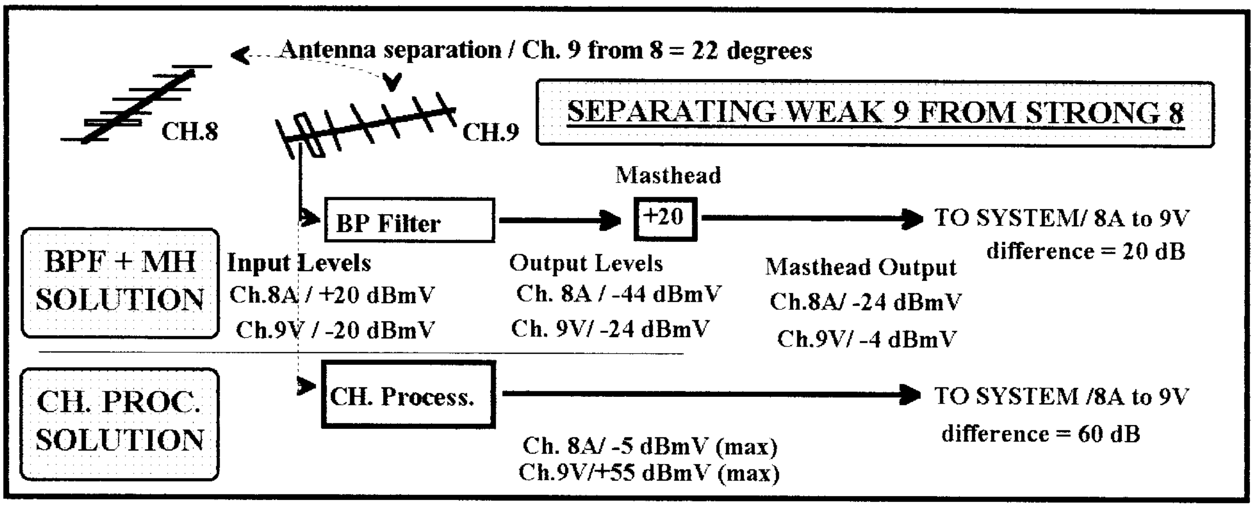
d) Noise figure of front end: 6 dB (VHF), 8 dB (UHF)

e) AGC: Output stays within +/- 0.5 dB for 30 dB input swing between range of 0 dBmV and +30 dBmV / +60 dBuV to +90 dBuV.

f) Selectivity of input circuit: Received energy -1.5 MHz below video carrier frequency and +1.5 MHz above aural carrier frequency attenuated at least 60 dB.

As a practical matter, consider channel 9 with video carrier on 210.25, aural carrier at 215.75 MHz. Channel 8 aural (the low side potential interfering carrier) is at 208.75 MHz; 210.25 - 208.75 = 1.5 MHz. The same number applies to possible interference to channel 9 audio from a strong channel 10 video carrier. Thus the selectivity or rejection of both adjacent channel nearest carriers is (-) 60 dB in a stock channel processor.

Now consider a channel 9 off-air signal that measures -20 dBmV / +40 dBuV against a channel 8 stronger signal that measures +20 dBmV / +80 dBuV. The off-air channel 8 aural carrier in our example is 40 dB stronger at the input to the channel processor than the desired channel 9. However, the selectivity of the channel processor will drop the channel 8 aural carrier by 60 dB resulting in an input to the



channel processor of -20 dBmV / +40 dBuV on channel 9 and for the aural carrier of channel 8 -40 dBmV / + 20 dBuV. Obviously at this point the adjacent channel (audio) interference problem is history.

And this footnote: This would not be predictably true if channel 8 was employing the NICAM (digitally modulated) aural sub-carrier. It would fall in 5.850 MHz above the channel 8 visual carrier or 203.25 + 5.850 = 209.100 MHz. At this point the channel 8 NICAM is only 1.15 MHz below the channel 9 visual carrier and the selectivity of the channel processor front end is approximately -32 dB at that point (rather than -60 dB at a point 1.5 MHz below). This means the channel processor would reduce the NICAM sub-carrier by 32 dB from its off-air level. NICAM is typically run at a carrier level greater than -20 dB reference the video carrier, so the true NICAM sub-carrier signal level becomes -32 dB (attenuation by being on downward slope of the channel processor input filter) plus (-)20 dB below the visual carrier level for channel 8; net result is the NICAM interference to channel 9 video will be -52 dB (or more) below the channel 8 video carrier level and -12 dB below the channel 9 video carrier level. These are tolerable levels even with NICAM present.

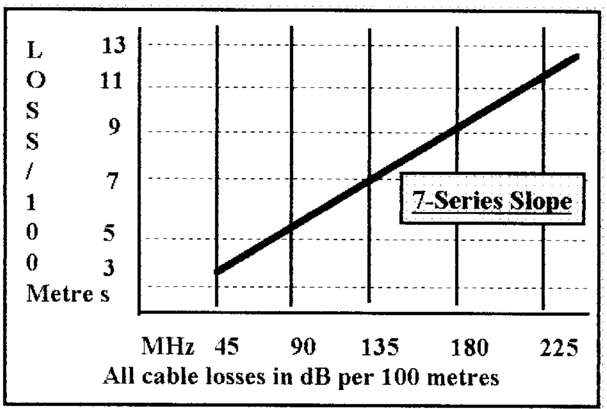
THE UHF CHALLENGE

System input signals on VHF can be processed on channel, or in a severe situation, processed at i.f. and replaced to the original channel or a new one selected by the system designer. UHF channels present special problems.

If you think of master antenna television systems as miniature community / cable TV systems it becomes clear that at frequencies in the 518-862 MHz range a number of distribution problems become acute. The first is the loss of the selected distribution cable. Compare the loss in various types of cable at 45 MHz (band I, channel 1), 230 MHz (band III, channel 11), 518 MHz (band IV, channel 27) and 862 MHz (band V, channel 62). From the table on page 15 it is clear that smaller diameter cables (such as New Zealand manufactured RG-59/U) are almost a disaster at bands IV and V. Slightly higher grade cables (RG-6/U) are better but still show significant losses at UHF. Still larger diameter cables, such as RG-11/U or the solid aluminium jacketed .500 and .750 begin to have manageable losses in bands IV and V.

But loss is relative. If the longest cable run from your 'headend' to the furthest TV outlet is only 100 metres, and you have ample amplifier gain, the losses are relatively unimportant; as

Loss at	TV Ch.	RG-59/U	RG-6/U	7 Series	RG-11/U
45 MHz	1	**6.4**	4.9	**3.8**	2.9
230 MHz	11	**12.9**	10.3	**8.3**	6.7
520	27	**19.8**	15.6	**12.6**	10.2
862	62	**25.9**	20.5	**16.4**	13.6



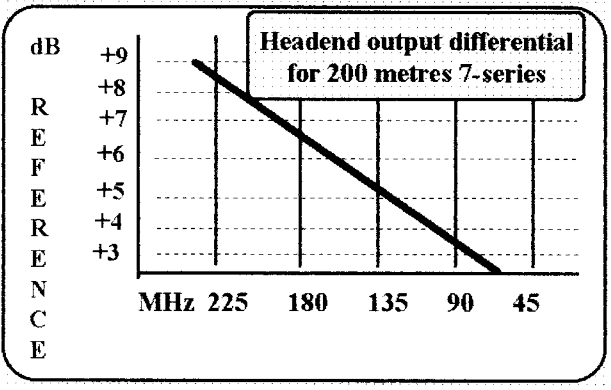
All cable losses in dB per 100 metres

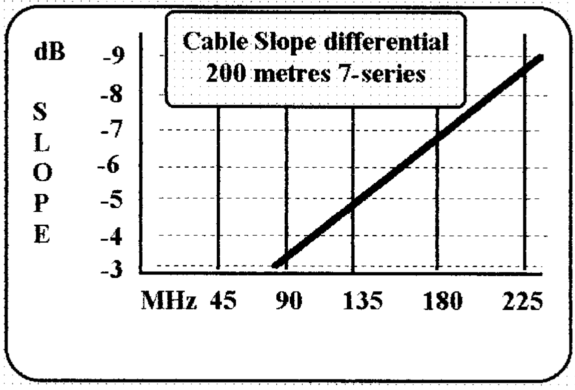
long as you can reach the last 'drop' (TV outlet) with 0 dBmV / +60 dBuV (a 'good picture').

Cable losses are 'sloped;' that is, they increase with frequency and if you intend to deliver relatively equal (in signal strength) levels on all channels at all locations, some careful engineering is required. Consider a 100 metre run of RG-59/U when compared to a 100 metre run of RG-11/U. At the end of the run in RG-59/U, without any splitters or taps, a channel 1 signal will have lost 6.4 dB, a channel 11 signal will have lost 12.9 dB. At the same 100 metre end a channel 27 signal will be attenuated 19.8 dB while a channel 62 signal will have dropped by 25.9 dB. In this example, channel 62 loss is greatest and if it is 25.9 dB then the 'gain block' amplifier required to insure that the same signal level fed into the amplifier comes out at the end of 100 metres will also require 25.9dB of gain. At the same time, the channel 1 loss of only 6.4 dB will require gain at channel 1 to be 6.4 dB.

Cable has slope loss; amplifiers have tilt gain. An amplifier designed to compensate for the slope loss of the cable will allow the installer to stair-step the output levels such that channel 1 gain is a fraction of channel 62 gain with channels 11 and 27 falling along the slope between these two numbers. Unfortunately, that solves the problem at the end of the line; it does nothing for the first TV set hooked onto the distribution line directly after the amplifier. While the amplifier tilt balances out the cable slope for the end of our example line of 100 metres, this balance only occurs for the end of the line. Closer to the amplifier the UHF channels are progressively stronger than their VHF counterparts all the way back to the amplifier output.

Now, do you really want to distribute UHF channels in the UHF range? The first and most important question to answer involves the TV sets that will connect to the system. Can they





even receive UHF? No? That answers your question since it is unlikely your MATV system customer wishes to replace all of his TV sets to allow one or two new UHF channels to be added to his system.

Therefore the TV sets in the facility play a considerable part in determining just how you will design the system. Sets originally designed to receive only four to six channels in the VHF spectrum (typically limited between channels 1 and 10) are perhaps the 'worst case' while modern, new varactor tuned VHF + UHF sets represent the 'best case.'

First layout the channels you have available for service. In Auckland, for example, channels 2,4 and 7 are in use and typically you would process these stations 'on-channel' with nothing more complicated than perhaps separate band I and band III antennas to assist in ghost elimination and signal balancing at the headend. Where possible you wish to avoid adjacent channels of operation (i.e., using two channels which share a common frequency boundary such as 7 and 8 with seven operating between 195 and 202 MHz and 8 operating between 202 and 209 MHz (202 being the 'common boundary'). Why?

If these were a CATV headend, every channel would be processed with something like a 'channel processor' and it would apply stiff AGC to the signal (guaranteeing its stability under varying reception conditions). And we would also 'turn down' the aural carrier level for each channel such that within a channel the audio sub-carrier was -15 to -17 dB reference that channel's visual carrier (see Tech Bulletin 9401T; p.25). In most MATV installations you have neither the AGC at the headend nor the control over the aural carrier level. Both of these steps are essential when you begin to stack up immediately adjacent (common boundary) signals in a piece of cable. Unless you take these steps, it is unlikely the average TV set will produce 'good pictures' 100% of the time under any and all varying reception conditions.

So we avoid these 'adjacent channel problems' by avoiding adjacent channels. In our Auckland example, with channels 2,4 and 7 received off air and processed on channel, that leaves us with the following non-adjacent channels to work with:

a) Channel 1 (there is a 3 MHz wide amateur radio assignment from 51 to 54 MHz so channel 1 is not common-boundary adjacent to 2).

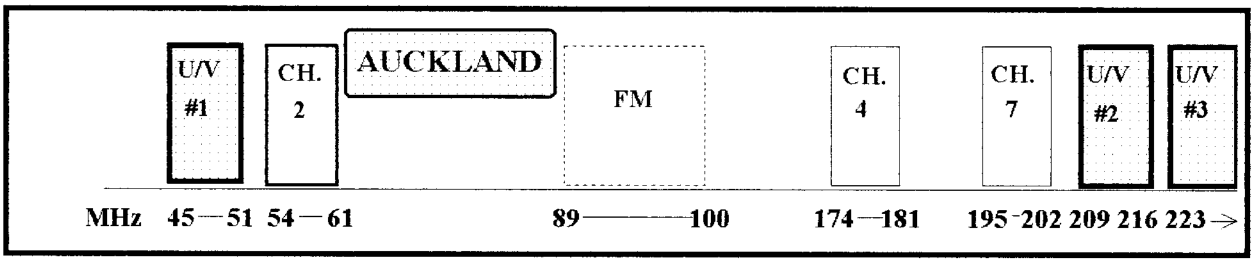
b) Channel 9

c) Channel 11

Channel 3 is common-boundary adjacent to 2, 5 and 6 to 4 and 7 respectively, and 8 is adjacent to 7. That leaves us with 9,10 and 11 of which we can use 9 and 11 without adjacent channel problems.

Note: Depending upon the quality of the UHF signal processing equipment, it would be possible to use 9,10 and 11 if the installer was careful to ensure that the headend output levels for 9, 10 and 11 were well matched, and the aural carrier level was adjusted downward to keep 9 audio out of 10 video, 10 audio out of 11 video.

If the TV sets in the MATV system premises are strictly VHF and strictly 11 channel sets (matching our own 11 channel TV spectrum), that's about all you have to work with. In the worst case that gives you three channels (1,9 and 11) to place UHF or other new signals on. Or, does it?



Now, if the TV sets employ tuners that cover the full range from 47 to 99 MHz plus 174 to 230 MHz you have additional options (most tuners cover this range even if we use only a portion of the 44-99 MHz range for TV broadcasting in New Zealand; check the TV set manual). If UHF will be carried at VHF, you are (down) converting the signals. The input channel is specified (as received off air) but the output of the UHF to VHF conversion can be (by design or order from the supplier) on practically any VHF 'channel' you wish. Remember, a TV 'channel' is a user designated 7 MHz bandwidth; not something the Ministry of Commerce Radio Operation Group creates.

7 MHz wide versus 8 MHz wide. Bands I and III TV signals are 7 MHz wide channels. Bands IV and V (UHF) are 8 MHz wide channels. In both cases the space between the video carrier and the aural carrier is 5.4996 (5.5) MHz. The UHF band IV and V channels are 8 MHz wide to accommodate the transmission of NICAM stereo within the channel (recall that at VHF the NICAM sub-carrier actually bleeds over into the next upper adjacent channel space). A UHF channel (such as TAB) will downconvert to a 7 MHz wide VHF channel without problems and there is no reason to consider the original 8 MHz bandwidth when designing a system that carries UHF at VHF; i.e., 7 MHz will do just fine.

a) 44 to 99 MHz (a not uncommon 'tuning range' for TV sets designed to 'auto search' and find signals) provides spectrum space for 7 TV channels each 7 MHz wide.

If channel 2 (54-61 MHz) is occupied, that leaves 44-51 for a second (UHF converted to VHF) channel, plus the balance of the space from 61 to 99 MHz (38 MHz).

However, we wish to avoid common boundary channelling so that rules out starting at 61 and going to 68. Does that mean the next available channel must be 68-75 MHz, leaving 7 MHz between 3 and what we might call 3A?

Not at all.

All we really need is sufficient 'guard band' spectrum space between channels to ensure that unexpected variations in system input levels or wild excursions of a channel's aural carrier does not cause interference with other channels on the system. Recall that channel 1 and 2 are not adjacent; there is a 3 MHz 'guard band' assigned to amateurs from 51-54 MHz.

This suggests a different approach to channelling for UHF channels that might be carried within bands I and II VHF (i.e., 44-99 MHz).

Consider:

Channel 1: A UHF converted station occupying 44-51 MHz.

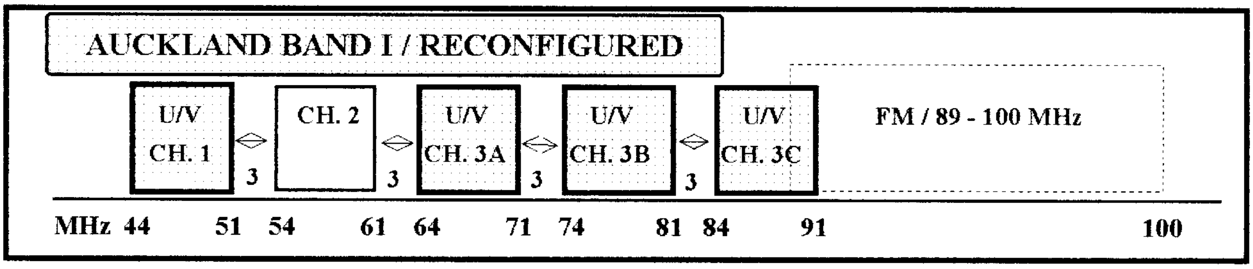
Channel 2: Off-air VHF occupying 54-61 MHz

Channel 3A: A UHF converted station occupying 64 -71 MHz (note **3 MHz guard band** on the lower side)

Channel 3B: A UHF converted station occupying 74 -81 MHz (again, note **3 MHz guard band**)

Channel 3C: A UHF converted station occupying 84 -91 MHz.

Dangers. If your MATV system will be located in a region where strong off-air FM broadcast signals are present, you could experience mild FM interference with the 5th channel shown here (designated 3C) as it's upper portion falls into the low end of the FM broadcast band. Using properly shielded coaxial cable will reduce or eliminate this possible problem; in the worst case you lose the use of channel 3C.


AUCKLAND BAND I / RECONFIGURED
U/V CH. 1
CH. 2
U/V CH. 3A
U/V CH. 3B
U/V CH. 3C
FM / 89 - 100 MHz
3
3
3
3
MHz 44 51 54 61 64 71 74 81 84 91 100

Challenges: The absolute guard band width required will depend upon the care with which you design your headend (remember AGC control and reduction of the aural sub-carrier levels are important). If signals are very off-air stable, and you can tweek on the sound to bring the carrier levels down to the (reference video carrier) level range of -15/-17, there is nothing that says the guard bands cannot be narrowed to 2 MHz. If this was done, you could then add a channel 3D in the just below 99 MHz region (subject to protecting against FM band II signal leakage into the system).

What this accomplishes is it makes room for as many as 5 new cable carriage channels in the band I spectrum. Now what about band III?

Channels 4 and 7 are occupied. Five and six are clear but 5 shares a boundary with 4 and 6 shares with 7. If you split the difference you can slide in a 4A as follows:

a) Channel 4: 174-181 MHz (off air)

b) Channel 4A: 184 to 191 MHz (a UHF converted to VHF channel)

c) Channel 7: 195-202 MHz (off air)

d) Channel 7A: 205-212 MHz (a UHF converted to VHF)

e) Channel 9A: 215 to 222 MHz (a UHF converted to VHF)

f) Channel 11A: 225 to 232 MHz (most tuners will handle this OK; a UHF converted to VHF)

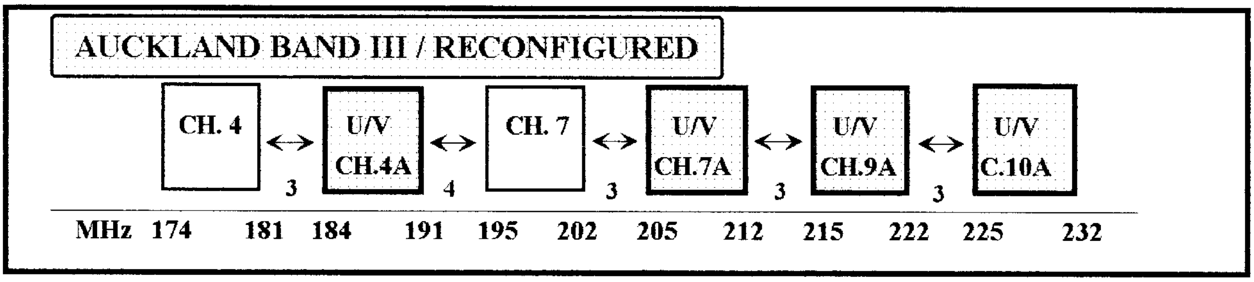
Now with ample 3 MHz guard bands we have a minimum of 5 band I TV channels and 6 band III channels; 11 total. That means that MATV systems in Auckland and Christchurch (where we presently have 8 off air signals including SKY) can be configured for all 8 present channels with growth room for three more. And all of this can be handled with a TV set that tunes only 44-99 and 174-230 MHz.

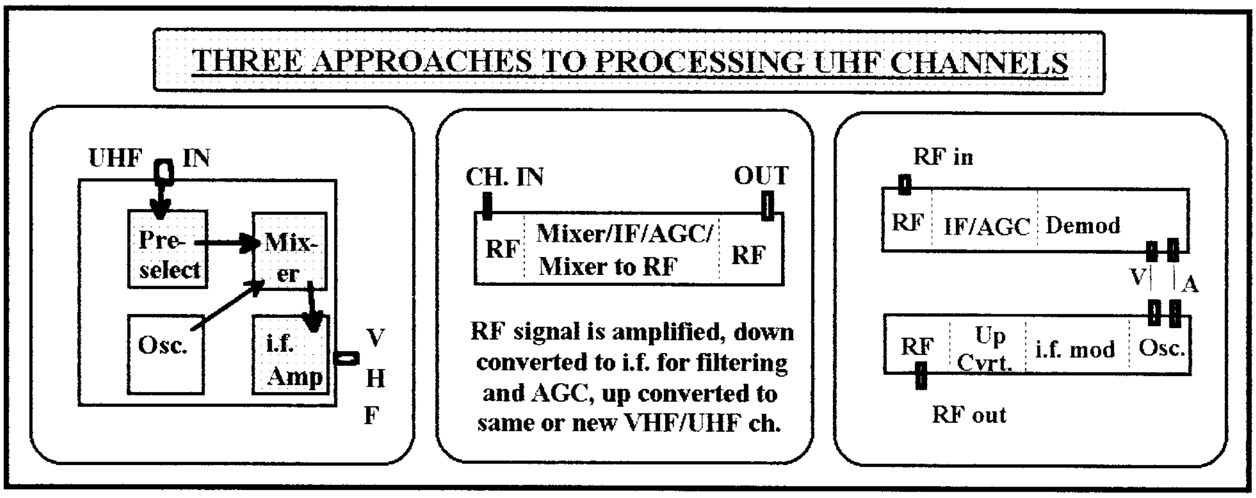
Note: Those MATV installations equipped with tuners covering the range 44-230 MHz inclusive of the region between 99 and 174 MHz offer room for another 7 channels, non-adjacent, using 3 MHz guard bands; a total of 18 channels, all with 3 MHz guard bands in place.

THE UHF CONVERSION TO VHF

There are three common ways to move a UHF channel to a VHF frequency. A direct frequency translation leads the list for simplicity, ease of installation and lowest cost. A UHF channel (such as channel 27/519.25 MHz) is fed into a mixer where it meets a locally generated oscillator (LO; 309.25 MHz). The 'mixing product' creates two new frequencies at the output of the mixer; 519.25 minus the local oscillator (=210.25) and 519.25 plus the local oscillator (=828.25). Following the mixer is an i.f. amplifier tuned to the selected output frequency. If this was 210.25 MHz, or TV channel 9, the output of the converter becomes channel 9. In the process the 828.25 MHz mixing product is 'lost;' discarded. The UHF antenna signal feeds into the converter's input, the new i.f. output (210.25 MHz) feeds into your MATV system.

A second approach is to select one of the channel processing units previously discussed. Here the UHF signal is down converted to the processor's i.f., the signal is bandpass filtered, amplified, and AGC is applied. The processor i.f. is then *up converted* to the selected TV output channel.


AUCKLAND BAND III / RECONFIGURED
CH. 4
U/V CH.4A
CH. 7
U/V CH.7A
U/V CH.9A
U/V C.10A
3
4
3
3
3
MHz 174 181 184 191 195 202 205 212 215 222 225 232


THREE APPROACHES TO PROCESSING UHF CHANNELS

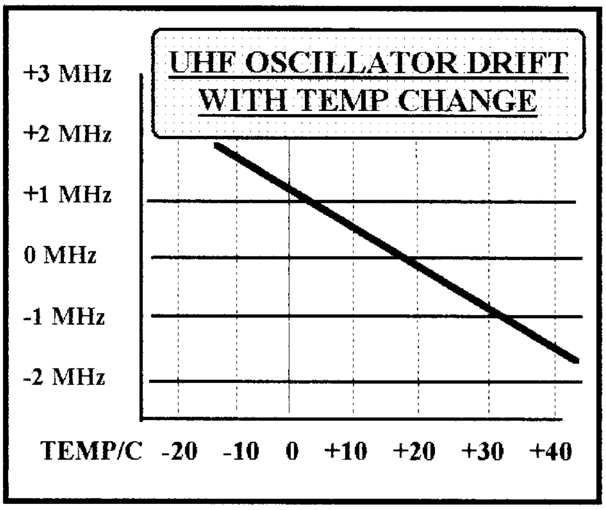
RF signal is amplified, down converted to i.f. for filtering and AGC, up converted to same or new VHF/UHF ch.

A third approach is to demodulate the UHF channel creating baseband video and audio (suitable to drive a monitor and sound system). This baseband is then applied to a modulator designed for the new channel and an RF carrier on the new channel frequency appears at the output.

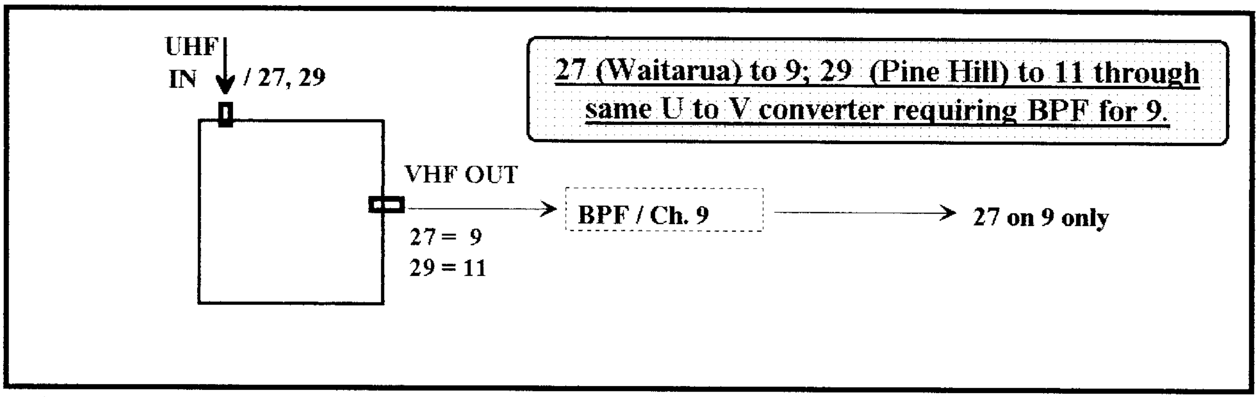
For cost reasons direct frequency translation is favoured for most MATV systems. An exception to this would be when the UHF channel is quite weak, or located in a dial position where there is adjacent channel interference (such as a channel 27 and a 28). In this case the channel processor is chosen because of its ability to separate adjacent channels, shape and filter weak signals while applying automatic gain control to the perhaps erratic input signal. The demodulate-remodulate system is favoured when some form of encryption is used by the incoming signal and it must be decrypted before being sent on to the TV sets connected to the system (i.e., rather than providing each TV set with a decryption box, the signal is decoded at the 'headend' and then sent on to the standard TV sets in its decrypted form.

Frequency translation converters are available over a fairly wide price range. What you are paying for is as follows:

a) Frequency stability: The local oscillator in the converter may or may not be crystal controlled. A crystal controlled LO will exhibit far better frequency stability than a so-called free-running oscillator. The operating environment of the converter, whether located inside of a heated room for example, has a big impact on the stability of the oscillator. Non-crystal controlled oscillators vary enough in frequency through temperature extremes (0C to +40 C) that the output frequency of the converter at VHF can vary over several megahertz. This in turn will cause the MATV system picture on that channel to creep just as if the TV set were improperly tuned. Some TV sets have sufficient AFC (automatic frequency control) to follow this excursion; others do not.



Crystal controlled LOs are rated for their frequency stability over a specified temperature range (such as -20C to +50C). Their stability within this operating temperature range is


UHF IN
/ 27, 29
27 (Waitarua) to 9; 29 (Pine Hill) to 11 through same U to V converter requiring BPF for 9.
VHF OUT
27 = 9
29 = 11
BPF / Ch. 9
27 on 9 only

specified as a 'window;' +/- 25 kilohertz is a common number.

b) Noise figure: The quality of the sensitivity of the converter is measured by its noise figure. A converter with a high noise figure will add a 'grain' to the video after conversion even with moderately high input signals (such as 0 dBmV / +60 dBuV). To cure a high noise figure the installer must add a low noise UHF masthead amplifier to the system to counteract the high converter noise figure (see Tech Bulletin 9303;p.15).

A converter noise figure higher than 6 dB fed with an off-air (UHF) signal weaker than -5 dBmV (+ 55 dBuV) will probably require a masthead preamplifier.

c) Hum modulation: Any frequency conversion device is capable of being modulated by the power supply's AC mains frequency. This means the 50 hertz AC signal appears as an overlay on the picture produced; typically as a light grey band that may move slowly up (or down) the screen. It is usually not sufficient to destroy the picture; just make it distinctive.

Hum modulation is specified as a - (minus) dB number. Any number lower than -55 dB is a cause for concern (i.e., -54 dB).

d) Maximum rated input: UHF to VHF converters may not be capable of handling very strong input signals. Their relatively simplistic design translates very strong off-air signals into a challenge for the mixer that produces the new i.f. output. Compare the manufacturer's specification (maximum recommended input) against the level of input signals you expect at the installation. The cure is simple enough; place an in-line attenuator (pad) in the input line until the off-air input is below the maximum rated input.

e) Image rejection: When your installation will have several UHF channels available (each of which requires frequency translation), the appearance of multiple signals at the input, all relatively strong, can cause undesired mixing or 'image' products in the converter. A converter designed to translate channel 27 to channel 9, for example, if presented with an equally strong channel 29 signal may well simultaneously translate 29 to 11. That could be useful; more likely it will create a new problem. If the converter was designed with an i.f. output peaked to a single channel (such as 9) the simultaneous translation of channel 29 to channel 11 will find the channel 11 output signal well down on the 'tuned gain skirt' of the channel 9 output. This will create a significantly degraded channel 29 on 11 at the same time 27 is coming out on 9. If you intended to mix channel 27/9 to the MATV distribution system from one converter and find 29/11 also going into the line at the same point any attempts to separately convert 29/11 in a second converter will be a disaster for the system. What you will have is 29/11 twice (as well, possibly, as 27/9 twice). And because the individual converter local oscillators will not be harmonious, you will create co-channel by having two 'stations' (the same signal, twice) on the same channel on your MATV system.

The answer to this problem is selectivity. Either the UHF input needs to be filtered ahead of the UHF converter (not inexpensive) or the VHF output needs to be filtered between the output of the converter and the input to the system.

With a 3 MHz guard band for your UHF to VHF channels, even the lowest cost free running oscillator U to V converters (if carefully installed) should not walk around in frequency so badly that a UHF channel moves into the frequency territory of another channel on the system. But, will the TV sets on the system be able to 'follow' the wandering channel? Probably not. The solution to this is to place the UHF converters in a reasonably temperature controlled environment where temperature changes cause more manageable LO frequency changes in the converters.

Unfortunately for the installer, lower cost UHF converters (i.e., those not employing crystal control) are also most likely to cause simultaneous frequency translation such as our 27/9 and 29/11 example. The money you save on lower cost converters may ultimately have to be re-spent to purchase bandpass filters to follow these converters to clean up the wideband outputs. And that suggests a new problem. The bandpass filters, operating at the VHF output channel of the converters, are very intolerant of frequency drifting. A change of just 1 megahertz in the output channelling at the VHF i.f. will move the UHF-now-VHF channel outside of the designed passband of the bandpass filter. Now your own filter will destroy the reception!

When in doubt about a converter product you have not previously used with success, arrange to test it before you bid it into an MATV system.

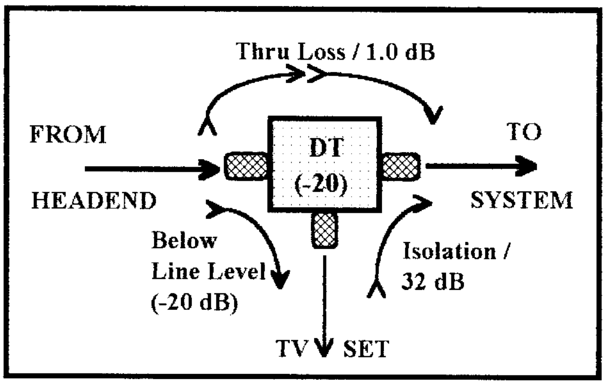
SYSTEM DESIGN

Visualise the MATV system as a conduit through which flows the combined output of the headend equipment. In the most simplistic situation, the headend is nothing more elaborate than an all channel VHF antenna delivering 1, 2 or 3 VHF channels to the sets.

It is the function of the headend to clean up any signals that require special handling, to re-space the channels if adjacent channels might be a problem, to ensure that no locally generated interference enters the system.

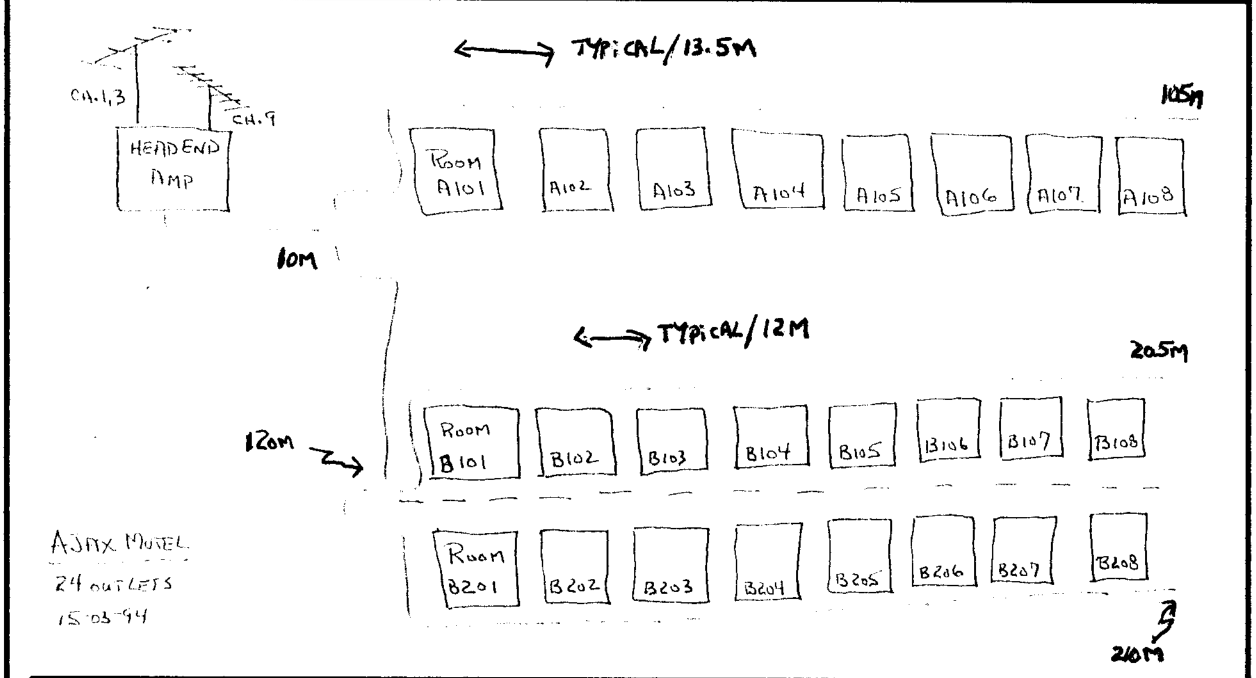
The ideal MATV distribution system is transparent to the signals after the headend work has been done. This means the individual TV sets connected to the system must not interfere with the reception of other sets connected to the system. The most common problem creating interaction between separate TV sets is the receiver local oscillator signal. If one receiver tuned to channel 11 has a set-internal LO falling inside of channel 5, it would not do for the MATV wiring to transport the LO inside of channel 5 around the system to other sets; especially if you are using channel 5 for another TV signal.

Isolation is the key word; each TV set is isolated from the system through a signal tap off unit that passes energy in one direction (from the headend to the TV set) but not in the other (from the TV set back into the system).



A directional coupler is a signal tap-off or coupling device designed to do just this. A two-way splitter is not such a device.

The layout of a system is an exercise in decibel addition and subtraction. You begin with a clean sheet of paper and a scaled drawing of the premise. The drawing will reflect



LAYOUT SKETCH/ 2 Building MATV System 210 metres to furthest TV outlet

the location of each TV outlet, the length of wire required to connect each outlet, and the location of the headend.

When you have this drawing prepared, make several copies filing away the original. The first step is to figure out how you can physically reach each outlet with a minimum of hassle. Some MATV systems are installed outside of the building running under the building eaves against the top of the wall. Others follow along an overhanging roof support system. Still others go from location to location through an attic crawl space. How you run the cabling, subject to the wishes of the customer, will have a big impact on the labour content for the job.

Virtually any installation will require penetrating walls to route the cable around, and locating splitter, tap-off and perhaps amplifier devices. Most customers will wish the cable to be out of sight, the passive and active devices placed so they are not temptations to children or adults.

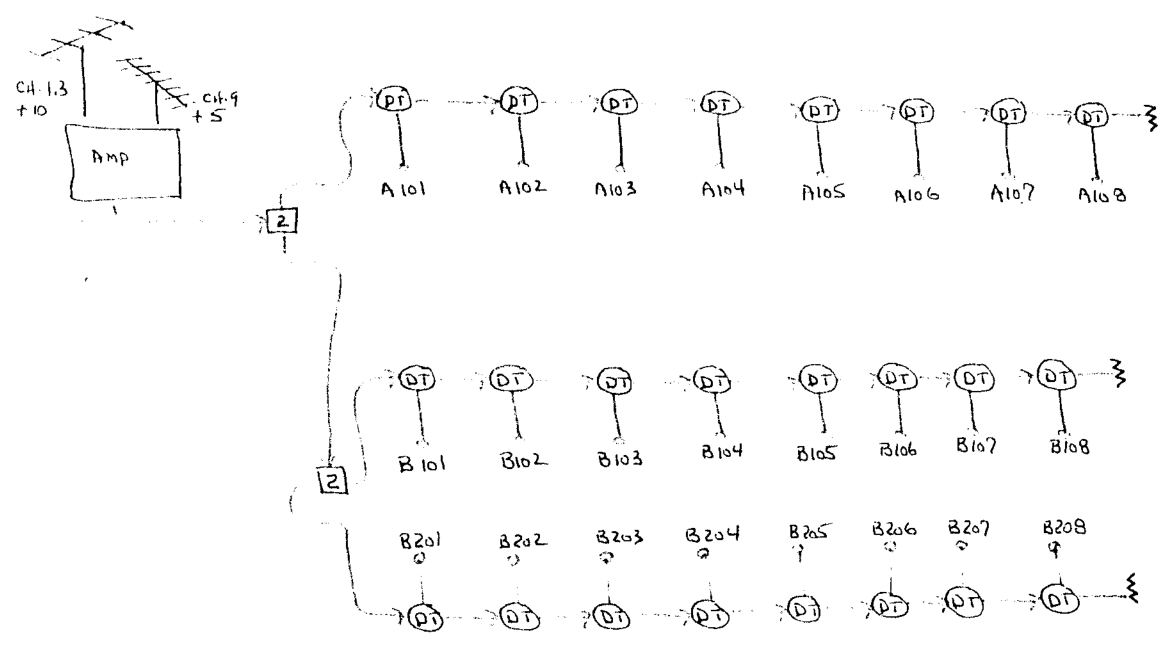
Wall penetration requires drill bits of sufficient length to extend through and reversible drills. Using the long (typically 450mm) bit requires both patience and skill blessed with good luck. It is handy to have a carpenter's device known as a 'stud finder' (locates wooden studs by their nails).

When you go to drill through a wall you are starting by selecting a location where the TV cable needs to pass through. This may be close to an AC mains outlet and your first concern is that when you drill through the wall you do not run into electrical wiring (or plumbing) in the process. It is amazing how fast the profit built into a contract installation can dissolve after you pay for destroying plumbing carried inside of a wall!

The walls or ceilings you have to penetrate with cabling become a factor in how the cabling is run. In other words, before you can lay the system out on paper, inspect the building(s) to determine how the cable can be run and what the customer will approve.

Once you have this settled, the system layout can proceed.

Make a tentative cable family selection; such as RG-6/U. Now you have a known 'loss factor' for the system based upon the loss of the cable



SKETCH #2 / A preliminary system layout with equipment in place

selected. Remember the system has to balance cable losses with amplifier gains to deliver appropriate signal levels to each location.

#1) Start with the TV outlet furthest from the headend and work backwards towards the headend following a physical routing that you know can be accomplished. Jot down the total length in metres or feet .

#2) Take that number and compare it to the known loss of the cable selected. To allow for future expansion, use cable loss for band III channel 11 as a basis for calculation (assuming you are not distributing at UHF; if you are, use 862 MHz for your calculations).

In our example here we have 210 metres of cable from the headend to the last TV outlet. This translates to 2.10 times (for 210 metres) X 10.3 dB of loss per 100 metres or 21.6 dB of cable loss to the most distant outlet. Set this number aside for the moment.

Between the headend and the last TV outlet we have cable loss (just computed) and passive losses. A passive device list would include signal splitters, signal tapoff units (i.e., directional couplers), even fittings. Cable loss varies with frequency being greater at higher channels (frequencies). True passive loss is equal on all channels; i.e., a two-way splitter with 4 dB of loss at channel 1 also has 4 dB of loss at channel 11.

Between the headend and the last TV outlet you will have a combination of cable loss and passive loss. The passive loss will add up to the same number regardless of TV channel frequency. The cable loss will vary with frequency..

Take your second sketch sheet copy and begin to layout a system starting at the headend. In our example there are two buildings so the headend output trunk line is split near the headend into two distribution lines. From the output of the splitter follow along the sketched in cable line until you arrive at the first TV outlet for one building. Draw in a symbol for a directional coupler. Continue this to the end of the line for the first building. At the very end of the line draw in a terminator (a 75 ohm resistor that 'caps' the line end).

Now go to the splitter line feeding the second building. Here we have two separate floors and logically a separate distribution line might run across the building for each floor (this may not fit your system but it is an example). A second two-way splitter goes in here at the start of the building with one cable leg then feeding horizontally across each floor level. At each TV outlet draw in a directional coupler ending with a 75 ohm terminator on each line.

Now go back to the beginning of the system and select one distribution line. Write in the splitter loss at each location (4 dB assumed) and then assign a nominal loss for each directional coupler.

Directional coupler (tapoff devices) have two separate 'losses.' The first loss of concern is known as the 'isolation value.' Directional couplers (also known as directional taps or DTs) feed the line (input) signal through the device. Inside of the DT is a miniature network that couples a portion of the signal on the line into the output port. DT values typically vary between -8 dB and -35 dB where - (minus) means the level of signal coming out of the TV set side of the port (or ports if for two or more TV outlets at the same location) will be lower than the level of the distribution line by the stated value; i.e., -8 dB would translate to a tap output 8 dB weaker than the distribution line signal at that point (+20 dBmV / +80 dBuV on the line; +12 dBmV / +72 dBuV at the tap output).

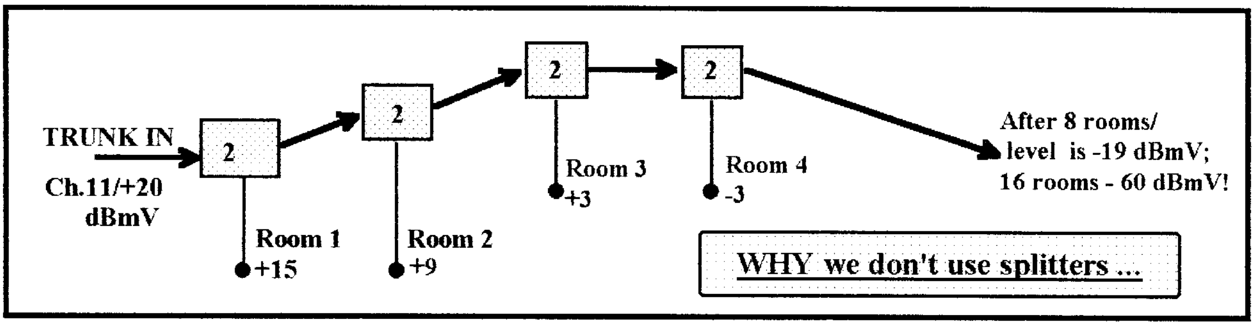
The beauty of the DT is that by having a selection of 'values' to choose from you can tailor the signal level delivered to the TV set to be virtually spot-on 0 dBmV / +60 dBuV. By knowing the cable and other passive losses between the headend and the DT location, you can calculate the distribution line signal level at the point where the DT installs. By selecting a DT 'isolation value' that will produce 0 dBmV / +60 dBuV at the end of the drop line (i.e., going into the TV set) you ensure the TV set at that location gets the proper signal.

The second 'loss' number of concern is the through-loss of the DT. In the process of siphoning a small amount of signal off of the distribution line the DT lowers the line level at that point. This is called 'thru-loss' and when computing the total losses in a distribution line you add this thru loss like you would a splitter loss; passive, or equal on all channels.

But what channel are we concerned with here? From previous discussion you know or suspect that the line levels will be highest on the highest channels, lower on the lower channels. The answer is that all calculations are done for the highest channel (frequency) in the system since because of cable's sloped loss quality the highest channel will always be the weakest channel. We'll deal with setting up the headend for this slope characteristic before we are done.

In our sketch sheet we now have a system layout with splitters and directional coupler tapoffs in place. Why not use more commonly available two, three or four way splitters for dividing signal to individual rooms?

Imagine using a two-way splitter for each room. The headend signals come to the input and one of the outputs feeds the room while the second goes on to the next room where another two-way splitter repeats the process. In doing this we are dividing the signal equally (that's what a two-way splitter does) between the first room, and, all of the rooms that follow. Now 50% of the signal level goes into the first room while 50% goes on to the second room. At the second room a second two-way splitter repeats; 50% of the available signal (25% of the original line level) goes into the second room, the other 25% goes on to the third room. By the time we get to the 8th room we are delivering around 0.39062% of the original signal to that room. The people back in room 1 get 50% of the



WHY we don't use splitters ...

available signal, the people in room four receive 6.25% of the original power and the poor folks in room 8 received 0.39062%. Obviously that is not a very good arrangement.

If the original line level was +20 dBmV / +80 dBuV, room one sees +16 dBmV / + 76 dBuV. Room 8 sees approximately -19 dBmV / +41 dBuV. Extend that to 16 rooms and the 16th room receives -60 dBmV / +0 dBuV. So splitters are fine for a few sets (up to 8 if done very carefully) but not for commercial MATV installation customer tapoff use.

Add to that that most splitters are bi-directional devices; local oscillator signals from one TV set feed back into the distribution line through the splitter and turn up as unwanted carriers for TV sets connected to the line.

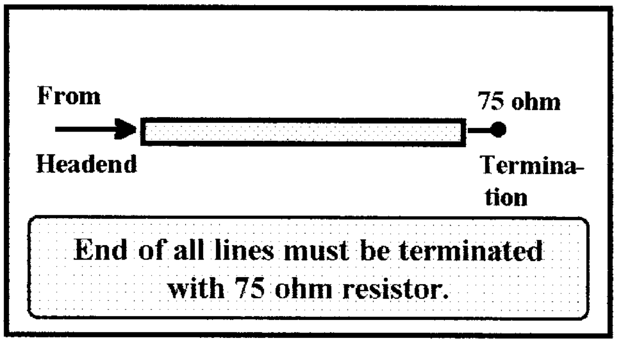
LINE to TAP 'ISOLATION'	Thru (Insertion)Loss of Tap DEVICE
4 dB	2.7 dB
6 dB	2.5 dB
8 dB	2.1 dB
12 dB	1.7 dB
16 dB	1.1 dB
20 dB	0.7 dB
24 dB	0.5 dB
27 dB	0.3 dB
30 dB	0.3 dB

1-outlet DT values; 2,4,8 outlets differ.

Directional couplers (DTs) have varying amounts of thru-loss. This is a function of the tap off 'isolation' and the lower the isolation the higher the thru-loss. A -8 dB DT, for example, will have 2.1 dB of thru-loss while a -35 dB isolation DT will exhibit 0.3 dB of thru-loss. Before we can assign real number values to the thru-loss, we must specify the distribution line levels so we can in turn arrive at the isolation values for the DTs we will use.

This requires a trial run of the numbers. For the trial run we will select a median value for thru-loss for each DT; 0.7 dB. In our motel example we have 24 total units, 8 on each floor leg. Thus the worst case DT thru-loss on any leg will be 7 times 0.7 dB (not 8; the last DT has thru loss but it only affects the 75 ohm termination level after the unit); or, 4.9 dB. Additionally, the last outlet on each distribution leg needs no less than +8 dBmV / +68 dBuV on the line at the point where the DT installs. Why? Because the lowest value DT commonly available has 8 dB of isolation, and to get 0 dBmV / +60 dBuV to the last TV set, we will need 0 dBmV plus the 8 dB isolation value, or +8 dBmV / +68 dBuV on the line at that point. Actually, because of a small amount of cable loss from the DT to the TV set, we will need another dB or two there as well. It is usually safe to plan a line so that it has no less than +12 dBmV / +72 dBuV at the end of line termination (a 75 ohm resistor).

Note. It is possible if you are resourceful to find DTs with isolation values as low as 4 dB and in the event you do so, your end of line



End of all lines must be terminated with 75 ohm resistor.

levels can be adjusted downward from +12 dBmV / +72 dBuV to +6 dBmV/ +66 dBuV.

Now we can back into the amplifier gain required for the headend.

#1) Assumed DT thru-loss (worst case, for the last unit on each leg) = 4.9 dB

#2) Splitter loss (worst case, for the two story building where two splitters are in the line back to the headend) = 2 x 4 dB or 8 dB

#3) Cable loss (worst case, channel 11 at 210 metres) = 2.1 times 10.3 dB per 100 metres = 21.6 dB cable loss.

#4) (+) 12 dB 'end of line' margin.

Sum these (loss) numbers: 46.5 dB.

Now go back to the headend plan. You know or have calculated the signal levels available from the off-air signals. One approach is to take the worst case off-air level (after conversion to VHF if the weakest signal is UHF) and then bring the rest of the signals 'into balance' with that channel. Remember that our goal is to make each individual channel as close to the same level at each TV set as possible. The easiest way to bring strong signals into line with the weakest signal is to install passive in-line attenuators (pads) on the channels that are strong.

Let's assume our weakest headend channel is +2 dBmV after being added to the trunk (master) cable and the rest will be adjusted to or around this number.

Our total loss (sum of passive and cable) was 34.5 dB. Our objective is to place 0 dBmV / +60 dBuV into the antenna terminals on each TV set on each channel. The answer is almost here.

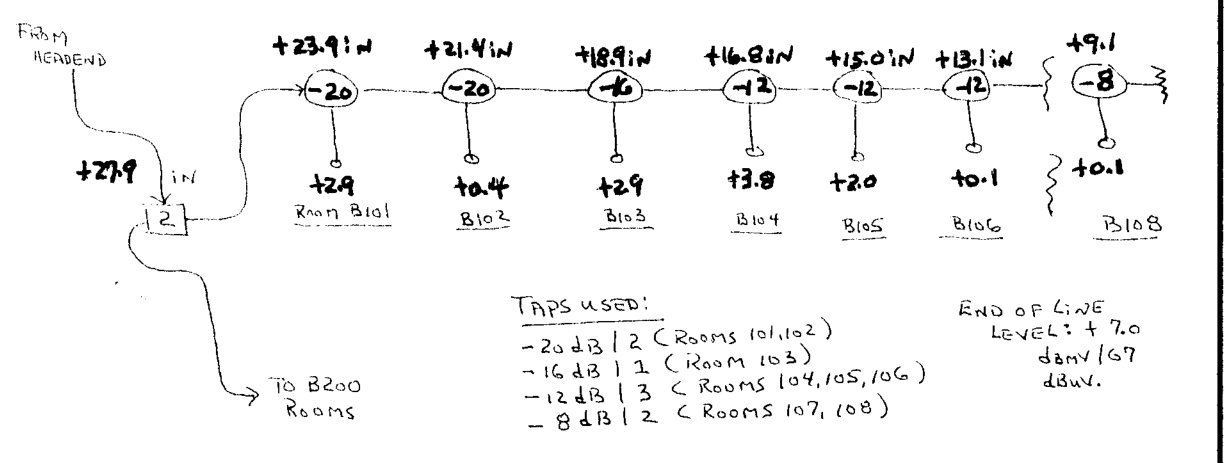
The amplifier gain required is the sum of all of the losses less the positive dB value of the weakest channel at the headend plus the end of line signal level required (+12 dBmV / + 72 dBuV in example given), plus 12 dB end of line. Our plus dBs are the +2 (dBmV/ +62 dBuV) on the weakest headend channel. Our minuses are: cable plus passive losses (-34.5) and the 12 dB end of line margin. So -46.5 plus 2 = 44.5 dB of amplifier gain required..

The amplifier goes at the headend, after the individual channels have been mixed into a common (single) trunk line. Some attention must be paid to the amplifier's maximum rated input, its gain requirement and the maximum output you will have. The input(s) should be within the specified input-range 'window' and the output should not exceed the rated output of the amplifier chosen.

Now for the actual DT isolation values. Knowing that our headend output level of all channels combined is +2 dBmV / +62 dBuV (on channel 11 even if no channel 11 is on the

Calculating headend slope by comparing losses at highest, lowest channels

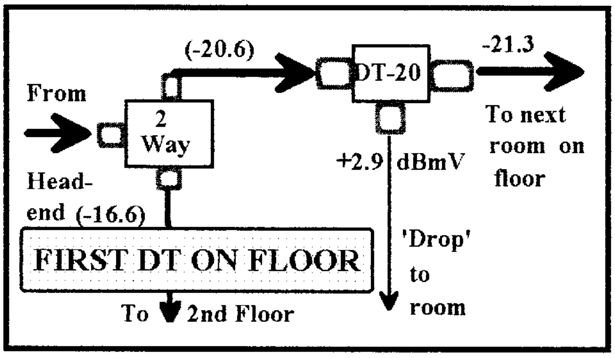
Highest Ch.	**Ch.11/ cable loss 21.6 dB**	+	**Passive loss 12.9 dB**	=	34.5 dB total
Lowest Ch.	**Ch.2 / cable loss 9.8 dB**	+	Passive loss 12.9 dB	=	22.7 dB total



SKETCH #3/ Plugging in DT values for one floor of our system.

system), we can compute the line level for each of the DT locations. This means starting out at the headend amplifier output with the known output level (+44.5 dBmV / + 104.5 dBuV) and subtracting out cable losses (at channel 11) and passive (flat) losses wherever they occur. We'll do one leg as an example.

The double floor building has a 4 dB splitter loss times two before we reach the first DT. That's 8 dB less signal. In our example, there is 120 metres of cable between the headend output and the output of the second two-way splitter. So 1.2 (a percentage of 100 metres) times the loss of our RG-6/U cable at channel 11 equals 1.2 x 12.6 dB or 20.6 dB total loss (with the passive loss). On the bottom floor the first DT is located right after the splitter so we assume the input to the first DT will be the same as the output of the splitter. If the total passive and cable loss at this point is 20.6 dB, then our headend level of 44.5 dBmV / +104.5 dBuV will be reduced by this amount. This means the input to the first directional coupler will be +23.9dBmV. We want 0 dBmV / +60 dBuV at the end of this drop line and if we assume 1 dB of drop line loss (between the directional coupler/DT and the TV set) we can calculate the isolation value for the DT. 23.9 dBmV / + 83.9 dBuV line level - 1 dB of drop line loss still leaves 22.9 dB to 'isolate.' The nearest DT isolation value is -20 dB. So at this location we place a DT with an isolation value of -20 dB knowing our signal level will be just above 0 dBmV / +60 dBuV (+22.9 - 20 or 2.9 dB) at the end of the drop line.



Repeat this process for each outlet, adding up the successively greater cable losses for each new incremental increase in distribution line length, and, adding the thru-loss value for each newly added DT as you go along. In our example we show how the sketch fills in for DT isolation values and distribution line signal levels to the end of the line. Note that we end up with a line level of +12 dBmV / +72 dBuV at the end of line termination.

All coaxial cable lines must be terminated to prevent ghosting (energy reflected from an open line end). A standard 75 ohm region carbon (not wire wound) resistor is the termination. You could also locate a -8 dB value (isolation)

DT that can go at the end of the line, with a terminator built in.

HEAD END ADJUSTMENTS

Because the coaxial cable 'sloped loss' is greatest on the highest frequency channel and our goal is to find equal signal level signals at each distribution line end, we compensate the headend output levels by tilting the signal levels. This means the highest channels leave the headend at the strongest level, the lowest (frequency) channels at the lowest levels.

How much tilt?

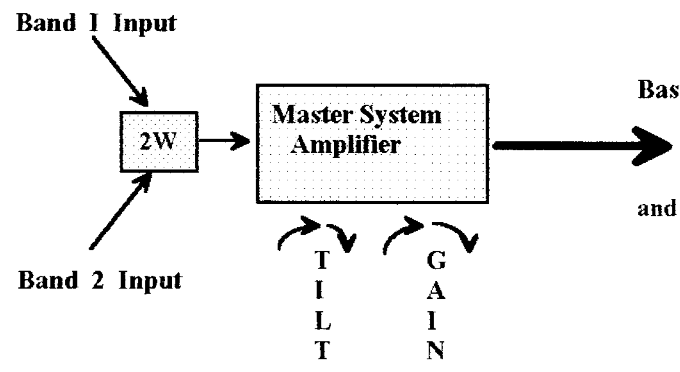
The answer is custom to each installation. Take the full length of the longest line in metres and calculate the loss in your chosen cable for that line length; once for the lowest channel on your system once for the highest channel. Here we ignore the passive losses and use only the cable loss. Let's assume it is 21.6 dB for channel 11 and 10.3 dB for channel 2. The difference (21.6 - 10.3) is 11.3 dB.

If we send out the highest channel (11) such that it is 11.3 dB stronger than channel 2, by the time we arrive at the end of the distribution cable both signals will have equalised to the same level because of the cable's slope.

Follow the same calculation procedure for your installation and once you know the slope differential between the highest and lowest channel on your system, use that number to 'adjust' your individual channel levels as they leave the headend. The slope differential between highest channel and lowest channel is your headend output differential

What is the best way to create this slope? The answer depends upon the amplifier you have chosen. Many amplifiers have an adjustable slope control with a range such as 10 dB. This adjustment will allow you to use a field strength meter (plugged into the test port on the amplifier, or if there is no test port, into the amplifier output directly) to adjust the slope to conform to your MATV system requirement. If the amplifier's available slope control range is not sufficient for your system, start by using all of the slope adjustment available and top that up by what follows.

If the amplifier you wish to use has no slope adjustment, your adjustments will have to be done at the antenna input lines before each signal is added to the input (to the amplifier) combiner. This can be both complicated and tedious because you are trying to keep the weakest input signal to the amplifier at least at the 0 dBmV / +60 dBuV level to maintain a quality picture on that weaker channel. The tools you have to work with are fixed in-line pads, and pre-amplifiers. By tilting the input to force the output of the amplifier to be tilted you accomplish the same thing you can do with an amplifier that contains a built-in slope control. Obviously if you can do slope adjustment with



Based upon system tilt required
set band I, III inputs to range
and fine tune tilt with amplifier control.

one amplifier control setting, you are far better off than with having to adjust each channel input individually.

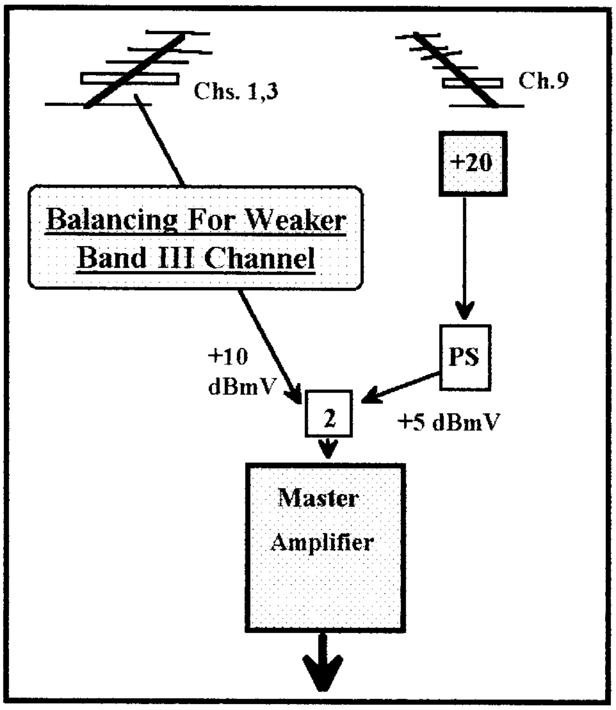
MIXING AFTER THE AMPLIFIER

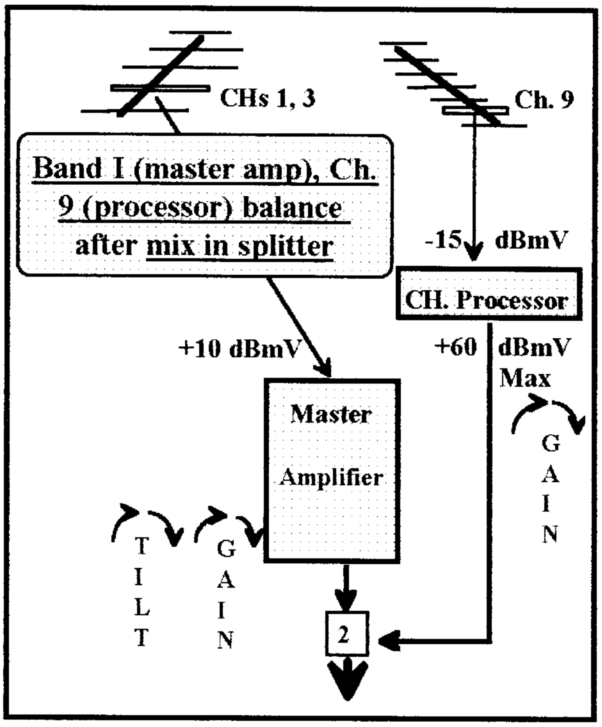
Let's assume a situation where you have two locally strong signals on channels 1 and 3 and a weaker signal on channel 9. Channels 1 and 3 are TV1 and TV2, channel 9 is TV3.

You can process channels 1 and 3 with a simplistic antenna and develop at least + 10 dBmV / + 70 dBuV for the headend amplifier input. But the channel 9 signal is down in the region of -15 dBmV even after stacking antennas (Tech Bulletin 9302; p.27). It is difficult to 'balance' signals this far apart in level for the system amplifier input.

There are two solutions and budget will dictate which you select.

If the antenna signal on channel 9 is -15 dBmV / +45 dBuV before any amplification, a 20 dB gain masthead amplifier on that antenna system would get you closer (to +5 dBmV / +65 dBuV). However, if the channel 9 signal has a tendency to vary up and down in level with weather conditions, you will have no AGC on it with a simple masthead. If the channel 9 signal is subject to strong increases in signal level because of weather, it is possible it would become so strong that the MATV amplifier could be overloaded at times.





An alternative would be to select a channel processor for the channel 9 signal. This would produce not only a well filtered and amplified signal with AGC, but it will also give you the output capability for the channel 9 signal equivalent to the full output of the channel processor. This would typically be +60 dBmV / +120 dBuV. Obviously you could pad this back down to around +10 dBmV / +70 dBuV to match the locally available channel 1 and 3 signals before going through the headend amplifier.

Another choice is to use the headend amplifier only on channels 1 and 3. Then after the headend amplifier use a splitter or directional coupler to add to the master/trunk output line the separately processed channel 9 signal. Since the channel 9 processor will develop far more output level than the headend amplifier on channels 1 and 3, use the output gain control adjustment on the processor to make the channel 9 line the proper level for your 'tilted' system.

In a similar fashion off-air FM signals can be separately processed (a separate antenna for FM, possibly a separate amplifier; operate the FM service signals such that the signal level of the strongest FM station is no greater than you would adjust a channel 4 TV carrier on your system if you had one on that channel).

And a locally generated movie service channel, through its own modulator or through the modulator in the VCR, can be added to the system. It can go into the system as if it were an off-air signal (i.e., ahead of the headend amplifier), or, after the headend amplifier through its own external single channel modulator / amplifier.

MULTIPLE AMPLIFIERS

Some MATV systems are so sizeable that a single headend located amplifier cannot reach the furthest outlets with the desired signal level. In this situation two or even three amplifiers may be required to complete the system.

When you use one amplifier to drive a second amplifier there are special considerations. The first of these is to be certain the input signal level(s) to the second amplifier do not exceed the rated input of the second amp. The next consideration is to do everything you can to feed into the second amp with a set of signals that are 'balanced' (flat) at the point of entering the second amplifier; ie., with no significant 'tilt.'

Operating two or more distribution style amplifiers in series (one at the headend, for example, a second midway through the system) is called 'cascading.' Cable TV system amplifiers are designed for cascading; not all MATV grade amplifiers are so designed.

All amplifiers create distortion products as they amplify. Distortion products manifest as waving lines on TV screens which indicate 'beats' or interfering signals generated by an amplifier are competing for spectrum space with the desired TV signals.

Distortion products multiply with each additional amplifier. Their existence may not be apparent (i.e., you see no interference) with a single amplifier. The addition of a second amplifier amplifies the distortion products from the first amplifier which are then increased by the products of the second amplifier.

Basically, distortion products will double each time you double the number of amplifiers in the system; thus two amplifiers have twice the level (3 dB more) of distortion of a single amplifier.

Quality manufacturers will specify the level of distortion present in a single amplifier. It is up to you to determine how many of a particular amplifier can safely be used before the distortion products are an annoying interference pattern on system connected screens.

If you plan a system with two or more amplifiers in cascade, the three specifications which help you judge the distortion products are as follows:

#1) Composite triple beat measures new carrier products (beats) generated when TV carriers amplified 'mix' within the amplifier. This 'mixing' is an inevitable part of amplifying; the trick is to keep the composite triple beats low enough that they never become apparent on the screen. CATV amplifiers (which may end up being 100 in cascade or more) have composite triple beats in the -65 to -70 region. MATV amplifiers are typically in the -60 (dB) region. When you have a number as low as -55 dB you can expect problems in cascade.

#2) 2nd order intermodulation is a measurement of harmonics generated within an amplifier. A TV signal using a channel such as 3C here, 84-91 MHz, 'doubles' in the amplifier and produces a new signal in the 168-182 MHz region. This new product can interfere with a signal carried on channel 4 (174-181 MHz). However, in MATV systems in New Zealand most band I channel frequencies will 'double' into harmless spectrum space where there are no other TV signals. The exception to this statement is channel 1 (44-51) MHz doubling into channel 3C (84-91 MHz). In MATV amplifiers numbers in the -75 (dB) region are considered good; as low as -60 dB is acceptable.

#3) Crossmodulation is the modulation of one video image by another. On the screen it appears not was waving lines or herringbone patterns (the two major images from composite triple beats and 2nd order) but rather as a 'film' of weak modulation product laying on top of the desired channel's picture. Because the 'phasing' between the two sets of modulation is poor you will usually see a distinct sync or frame bar laying horizontally across the screen with weak (to not so weak) video from the second signal on top of the primary signal. In CATV amplifiers a number in the -65 to -70 region are acceptable. In MATV, numbers in the -58 to -61 region are acceptable.

In all distortion product situations the system planner is in control. If you are only using a single amplifier (i.e., not in cascade), select product with reasonable distortion product numbers. If the system will have two or more amplifiers in cascade, pay some attention to these specifications.

When you plan and install the system using amplifiers in cascade, pay particular attention to:

#1) The rated output level from the first amplifier. 'Pushing' the amplifier to or beyond its rated output level (measured by the signal level leaving the amplifier on any channel) causes distortion products in the first amplifier to rise sharply. Using the manufacturer's data sheet as a guide, 'back off' the output of the first amplifier by 3 to 6 dB; i.e., derate it to ensure the distortion products are reduced.

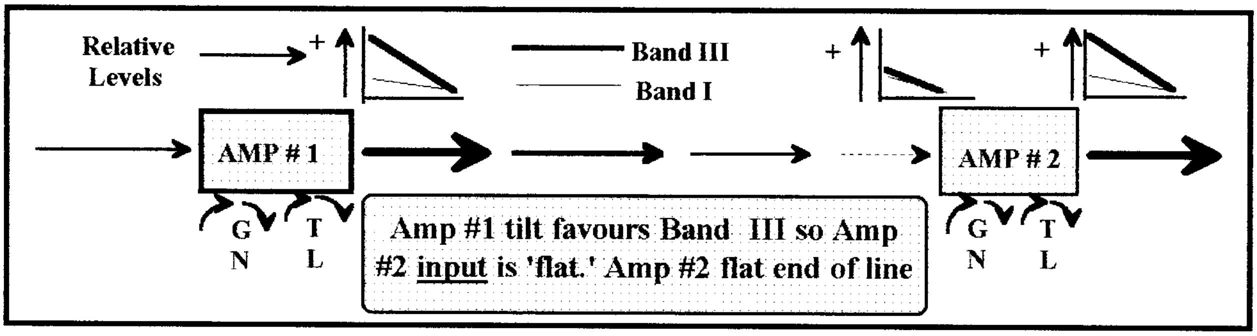
#2) The rated input and output of the successive amplifiers are important. By careful adjustment of the system tilt at the first amplifier, arrive at the second amplifier such that the input is as close to 'flat' (i.e., all channels at about the same level) as possible. Also ensure you do not overdrive the successive amplifiers; if the recommended input is +6 dBmV / +66 dBuV, do not exceed the recommended number. Next derate the output of successive amplifiers by 3 to 6 dB for the same reason you did so with the first amplifier.

Most distortion products 'after the fact' (i.e, they happen, and now how do you fix them) can be improved by merely placing an in line attenuator / pad at the input to the amplifier that first shows the products. Padding the input down, and then turning its own output level down, backs the amplifier off from its 'intercept points' (where distortion products run amuck in the amplifier).

HIGH OUTPUT AMPLIFIERS

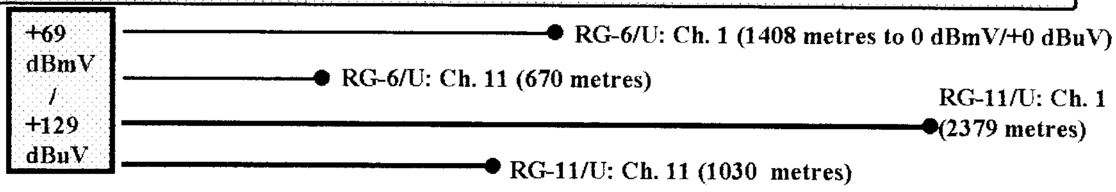
Although most MATV systems are designed around broadband amplifiers it is possible to follow CATV practices and individually process and amplify each channel to a quite substantial output level before doing 'combining' (joining all of the channels together into a single cable).

Strip amplifiers offering as much as 3 volts output (+69 dBmV / +129 dBuV) on a single channel are available. Applications would include very long cable runs or complex



Amp #1 tilt favours Band III so Amp #2 input is 'flat.' Amp #2 flat end of line

HIGH OUTPUT AMPLIFIERS: How Far at What Frequency in Which Cable?


+69
dBmV
/
+129
dBuV
RG-6/U: Ch. 1 (1408 metres to 0 dBmV/+0 dBuV)
RG-6/U: Ch. 11 (670 metres)
RG-11/U: Ch. 1 (2379 metres)
RG-11/U: Ch. 11 (1030 metres)

buildings with relatively short cable runs combined with many close together signal splitters and directional taps. At +69 dBmV / +129 dBuV output level a 1,408 metre length of RG-6/U cable would transport a channel 1 signal to a 0 dBmV / +60 dBuV level. In RG-11/U, the length would be 2,379 metres. At channel 11 the length would be 670 metres in RG-6/U, 1,030 metres in RG-11/U.

Most high level output amplifiers require inputs in the region of +12-20 dBmV / +72-80 dBuV to produce outputs near +69 dBmV / +129 dBuV.

With such high output levels special attention must be paid to the cables that interconnect lower level stages to the high output amplifier. Cable shielding is important to prevent a feedback loop (the high level output leaking back into a lower level input) from developing. To discourage feedback, use well shielded cables, physically separate input (low level) and output (high level) lines and make sure all connectors are tight. A loose shield-nut on an F style fitting will leak signal.

THE HARDWARE

MATV cable should be selected on the basis of its shielding integrity and its losses. Shielding integrity is listed first because ingress from outside interference sources is unfixable once the cable is installed; too much loss can be cured with more amplifier gain. However, there is a cost trade-off between lower loss cables and spending more money for amplifier(s). It usually works out that you are better off selecting lower loss cable than selecting higher gain amplifiers.

Connectors for cable should match the connectors required for the splitters, amplifier(s), directional taps. If there is a temptation to mix connectors by selecting splitters commonly available with Belling-Lee fittings, discard that choice and stay with F fittings throughout the system. There is a (typically $40) tool that allows you to properly crimp the outer ring on F fittings. Buy and use it; don't try to save $40 and substitute pliers for the proper tool. The F fitting's integrity depends upon the physical pressure of the crimped ring to the cable shielding and pliers that compress unevenly the ring cannot match the concentric crimping tool for efficiency.

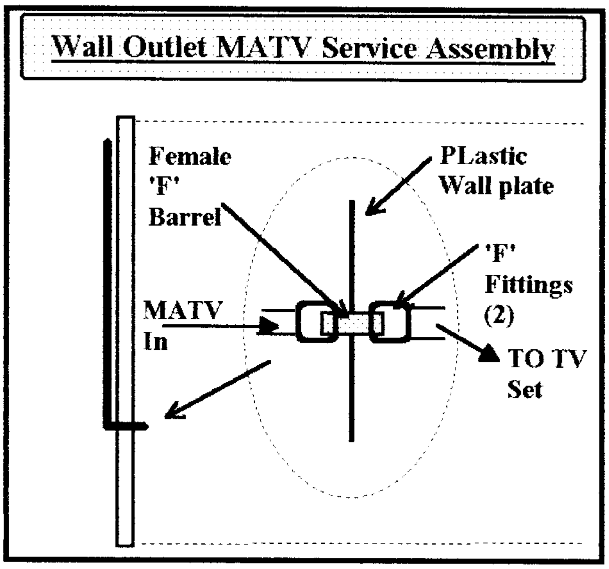
Amplifiers are selected for the job based upon gain required. Amplifiers with built-in gain (output level) and slope (to match cable tilt) are preferable because they make your job of system set-up easier. Amplifiers which have 'just enough gain' should be avoided; buy a few extra dB of gain to allow for system ageing and to cover miscalculations in your layout.

Directional taps have only recently become commonly available in New Zealand. They exist; look for them and avoid the use of splitters as MATV outlet service devices. Most DTs are housed in small weatherproof containers and can be safely installed out of doors. DT values reflect the isolation of the tap from the line; -8 dB means the DT output to the TV set will be 8 dB below the line level at the point where the DT is installed.

Splitters using F fittings are significantly better than splitters using Belling-Lee fittings. Most B-L fitting splitters were not designed to operate outside and moisture ingress is a major problem. The B-L fittings demand very close attention to detail and even when they are installed perfectly the fittings are mechanically unsound and electrically inferior to F series. Yes, it takes more looking to find F fitting equipped splitters. Find a source and stay with it. Anything that can be bought off the rack at Dick Smith is probably not adequate for a professional MATV installation.

Headend equipment should continue the F fitting mandate. Most equipment has been designed to mount against a wall; many installations screw the equipment to a piece of plywood installed for this purpose. It is helpful to draw out on the plywood a schematic of the headend, labelling signal levels at various points after the installation is complete. This will greatly assist future trouble shooting if the technician can look at the 'board' and see what levels were present when the system was turned on and proofed. Most headend gear is not weatherproof, and UHF to VHF converters that are not crystal controlled should never be mounted where air temperature changes are severe (such as directly above a clothes dryer in a motel laundry room). Lint and dirt in the headend room can be a problem if equipment is mounted such that adjustable pots (gain, slope) are positioned to collect trash from the air. Fashion small covers for adjustment pots if you believe air contaminants could be a problem; even a simple plastic 'flap' taped over the adjustment will do. Take an indelible pen and mark all slope, gain and other control settings on the equipment next to the adjustment so you will know in the future where the pot was set when the system was installed. It is a never ending source of amazement how people who own motels will stick a screwdriver into an adjustment and 'tweek' without any regard to what they may be doing!

Headend cabling (between devices) should be flat against the wall / board rather than looping 'outwards' into the room. A cable loop sticking out from the equipment 30cm is asking to get caught by someone's broom or mop and ripped from the equipment. You've not experienced a fun service call until you have been called out at 9PM at night to redo a coaxial patch cable which the motel manager reluctantly admits he 'snagged' while walking by the equipment. Even worse than that is when they try to repair it themselves by bundling Scotch Tape around the busted coax and fitting hoping it will renew the contact required.


Wall Outlet MATV Service Assembly

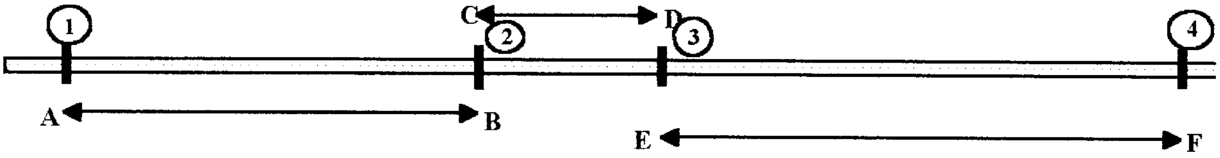
At each TV outlet location you can bring the coaxial cable through a carefully positioned and drilled hole directly into the room. Here you have a choice:

#1) Continue the coaxial cable (uncut) directly to the TV set, or,

#2) Mount a (plastic) wall plate on the wall with a female-female nut secured barrel (splice) fitting through a hole in the centre of the plate. In the latter case you have a way to disconnect the TV outlet at the wall leaving no cable behind. However, the wall plates cost extra, the barrel costs extra, and you have another F fitting to install.

Coaxial cable can be stapled or secured to the walls using hardware designed for this purpose. The operative word in the sentence is "designed' (for). Normal staples will crimp the cable and that is a good way to create an unusual ghosting

Staples, wire-brads that 'crimp' cable can create ghosts, signal 'suck-out' (loss)



1 - 4 / Staples causing crimp in cable

A - B, E - F = Longer distances dangerous to Band 1 signals; C - D dangerous to band III signals

problem on some channels at some outlets. The physical cable distance between 'crimp' points will be an unfortunate portion of an electrical wavelength on some channel in the system. When the cable is crimped (made smaller by the pressure of the staple) the distance between the centre conductor and the shield portion of the cable is reduced. This creates an 'impedance bump' in the cable at that point; a mismatch in the cable proper. A series of these 'impedance bumps' causes the line segments between impedance bumps to act as 'traps' for signals that happen to fall into a wavelength versus bump-to-bump spacing pattern. The net result can be:

#1) Ghosts on one or more channels caused by these impedance bumps;

#2) An unexpected and seemingly unexplained loss of signal level on one or more channels.

You can avoid this frustration by not using staples that were designed to nail together battens or plywood. Staples created for affixing your selected size of coaxial cable exist; search them out. In lieu of that, use plastic straps or cable clips which were designed to not crimp cables.

The best rule is to allow the coaxial cable to hang where it will as long as it is not going to get in harm's way. The fewer staples/straps/clips you use the better off you will be electrically.

TEST EQUIPMENT

At the very least you need a signal level/field strength meter of modest accuracy. It is not possible to set up a system properly without one (although it is possible to luck out by computing levels on paper and guessing alot).

A signal level meter will not reveal the presence of signal beats, crossmodulation or degraded off-air signals (such as a ghost filled picture coming off the antenna). This suggests a small, preferably battery operated, TV set.

Most professionals will install at the headend, right after the amplifier output on the trunk line, a 'test point' directional coupler. Although some MATV amplifiers have their own built-in test points (typically -20 dB reference the actual amplifier input/output), test points can go bad. By installing a DT in the line at the headend you have a place to return to for service work where previously recorded signal levels can be checked. It is not a bad idea to write down the channel levels from the test point on the wall / board as a permanent record. If all of this wall / board writing upsets your professional image, do it on a piece of paper, enclose the paper in a piece of plastic and staple/nail/tape it to the board for future reference.

TROUBLE SHOOTING

Most MATV system service calls are related to one of the following:

#1) A human mistake; a cable is cut, nailed through, yanked out. Loose connectors are a common problem. Make sure you tighten each one properly (but don't over torque!). If this problem persists, you can buy and install 'locking connectors' that require a special tool to disconnect. This will keep motel tenants with a passion to play with fittings from getting at the connectors.

#2) Variation in off-air levels. If one or more of your signals would be considered 'fringe' in quality, you can expect some variation in reception quality from day to day. If the job will not allow you to install AGC/filter corrective channel processors, the customer will need to understand 'up front' that fringe quality signals vary in strength and clarity. Adding TV3 from a distant transmitter is a doable challenge but the client will need to appreciate that on average the service will not be as stable as the nearer TV1 and TV2 transmitters.

#3) Signal leakage interference. Several hundred metres of cable strung throughout a facility is an open invitation for non-desired signal entry to the system. Selecting quality, well shielded cable is a first step to avoiding this problem. Using directional taps rather than splitters to connect up each outlet is a further step since this eliminates any single malfunctioning 'drop' (room system) from sending interference back into the system.

#4) UHF oscillator drift in converters. Even crystal controlled converters should not be installed where the laundry room clothes dryer blows hot air on them. Select the best unit the job can afford, and be careful where you install it.

SUMMARY

MATV system installation is rapidly becoming a sizeable mini-industry in New Zealand. As new UHF channels come on air the need for master antenna systems done with reasonably careful planning will expand rapidly.

There is money to be made installing such systems; there is money to be made by selling a 'service contract' for the ongoing maintenance of such systems.

The advent of multiple channels of satellite delivered television during 1995 will cause many motels to consider adding satellite sports, news and entertainment channels. We'll visit this special subset of MATV system installations in our October edition of Tech Bulletin (issue 9405T).

SOURCES FOR MATV PROFESSIONAL EQUIPMENT

1) **FAR NORTH CABLEVISION , LTD.** (P.O. Box 330, Mangonui, Far North)

Blonder Tongue (USA/PAL B and D) UHF to VHF crystal controlled converters, VHF and UHF bandpass filters, channel processors, frequency agile 47-550 MHz broadcast spec modulators/demodulators and specialised headend equipment.

2) **LINCRAD AERIALS LTD.** (17 Washbournes Rd., Christchurch 4; Tel. 03-348-0659, FAX 03-348-4043)

GME/Kingray, Wisi, Sadelta active (electronic) and passives including cable, connectors.

3) **SIGNAL MASTER LIMITED** (P.O. Box 12-373, Penrose, Auckland; Tel. 09-525-5599, FAX 09-525-8039)

VHF/UHF signal preamplifiers from Nippon, DX, others; modulators, channel processors, Comm/Scope cable, connectors, Sadelta signal level meters, MATV/CATV directional taps, splitters, amplifiers.

NOTE: Electronic Technology Services Association, Inc. (ETSA) annual Conference in Hastings September 15-18 (1994) will include training sessions for MATV system design and installation. Membership is ETSA is not a prerequisite to attending these sessions. For information contact ETSA at 09-489-8175.